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Castor way

A trip to a kart race inspires consideration of how to use this angle

Last weekend, I indulged in a multi-faceted motorsport trip to Belgium. It started with a visit to Spa ahead of the fourth round of the European Le Mans Series season. I couldn't help but admire the sight of LMP2s at full throttle up Eau Rouge: it remains one of the most beautiful things you can see in racing. On the Friday and Saturday, I went to see some friends at Belgium's other major circuit, Zolder, for the latest edition of a 24-hour race first run in 1977. The GT cars, busy negotiating a grid full of touring car backmarkers, clearly exposed the gulf between the few professionals and the amateurs. However, exactly that mix delivered a very unpredictable race. I then headed for nearby Genk, where the IAME Karting series was holding its European round on the Sunday. There, the youngsters were having a ball overtaking and being overtaken. You could easily gain or lose five places in two corners, which is, brilliantly, standard stuff in karting. It was at Genk where I found the inspiration for my latest *Racecar Engineering* column.

Castor is crucial

While closely looking at these nicely polished and mostly brand-new karts, I realised again the importance of castor on these rigidly suspended racing machines (until the rear inner wheel is lifted to get the thing turned in). Consider its single tube 'spool' rear axle to understand the importance of castor in these chassis' dynamics. I guess that setting up the kart is mainly about finding the perfect balance between that castor angle and the chosen stiffness of the chassis.

Falchetto's example

In 1922, Battista Falchetto, technical director on the Lancia Lambda project, designed the first fully functional monocoque car to reach production. The advantage was a huge weight saving while multiplying by more than 10 the chassis' torsional stiffness compared to that of a typical ladder chassis car of the time. Today we are happy to see progress of a single digit percentage in both weight reduction and resistance to torsional stress, within ISO standardisation regulations.

Back to castor, though. While a kart badly needs it to turn in, a racecar has a far larger window to play with, yet the principle is the same. The kinematic effect of any geometry, including castor angle, will result in a change in cross weights with turned steering. It helps to counter understeer by holding back on some vertical load on the inner front wheel. This load would otherwise migrate to the outside of the wheels, and the effect is obviously reversed on the inner rear wheel. In other words, the limit of castor is traction capacity.

Some of us may remember the days when a weak chassis (with regards to torsional stiffness) proved faster on a wet track compared to more advanced cars that boasted far stiffer monocoques. The reason was that this weak chassis was easier to drive and, more specifically, could drift in the rain compared to the better 'dry' car. The kinematic effect of castor was much lower on a torsionally weak chassis and made the four tyres operate under slower and more stable loads. Of course, such a car is significantly easier to drive, considering the endless spikes in a steering wheel trace for the data of a car that is being driven in the wet. Each spike represents both a solution, for the car's direction, and a problem regarding the loads on the poor tyres.

Study topic

I would have loved to test the effect of zero or near-zero castor on a modern racecar in the wet, comparing it to the standard kinematics exclusively studied for dry, high grip conditions. Sadly, I never did. So, who of today's engineering students is up for an experiment? Who wants to design a front upper wishbone to test the one thing that has hardly been done before?

I only say hardly, though, because even Falchetto's Lancia Lambda featured a perfectly vertical sliding pillar independent front suspension with …no castor.

While a kart badly needs [castor] to turn in, a racecar has a far larger window to play with, yet the principle is the same

Castor is the angle between an imaginary vertical line through the wheel's centre (when viewed from the side) and the swivel pin of the suspension. It can be set positive, negative or neutral

Steep climb

It took Subaru 20 years to clinch a GT300 title with the arrival of the second-gen BRZ in 2021, but that achievement has proven to be a tough act to follow

By JAMIE KLEIN

Subaru's racing programme focuses on Super GT's second-tier GT300 class, where domestic cars go up against globally recognised FIA GT3 models. The current BRZ racer is built to GTA-GT300 regulations, meaning it is only active in Japanese motorsport

'We feel we increased the car's base performance… but we couldn't get the tyres to last the full distance in a race. I think this was the biggest factor in our lack of results'

Masahiro Ozawa, general manager at R&D Sport

Body-wise, the 2024 Subaru BRZ is only a mild update on the previous season's car, with more front-end downforce and a more effective underfloor, but a change to the qualifying format with respect to tyres has hampered the team

While the 'big three' Japanese auto makers, Toyota, Nissan and Honda, battle it out for supremacy in Super GT's top GT500 class, there is a sometimes overlooked fourth manufacturer chasing glory with a factory team in Japan's biggest racing series, albeit in the second tier.

Three years ago, Subaru finally achieved its ultimate goal of winning the title in the series' lower GT300 division after two decades of trying. That success coincided with the debut of the second-generation BRZ, one of a growing number of models conforming with Super GT's homegrown GTA-GT300 regulations (sometimes referred to as 'JAF' rules, a reference to their former official name) that fight against the FIA GT3 machines which make up most of the field, as well as the sole remaining 'Mother Chassis' model.

While title success with the new BRZ came immediately, replicating the feat has proven difficult. In 2022, the R&D Sport-operated Subaru team fell agonisingly short of back-to-back titles after driver Hideki Yamauchi spun in qualifying for the season finale at Motegi, leaving the team powerless to challenge.

Then, last year, an inability to make the Dunlop tyres last meant Yamauchi and his co-driver, Takuto Iguchi, were not in the hunt.

Tyre trouble

For this season, Subaru has worked closely with tyre supplier, Dunlop, to try and eliminate the understeer that plagued its title aspirations last year and to repeat the magic of 2021 / '22, when the BRZ was one of the benchmark cars in the GT300 field, in terms of consistency.

'Last year was quite a tough season,' reflects the team's general manager, Masahiro Ozawa, who has been in post since that title-winning 2021 season. 'We feel we increased the car's base performance, and we didn't experience much [reliability] trouble, thanks to the level of our mechanics and engineers, but we couldn't get the tyres to last the full distance in a race. I think this was the biggest factor in our lack of results.

'This time, we've focused more on this area than in other years, on trying to adjust the car balance to look after the tyres more. During the off-season we've been working hard to try and address this, even though

Tyre durability and understeer have been major challenges for the Subaru team the past two seasons, so recent development has focused on car balance

testing chances are limited. We were the only team that took part in every GTE [GT Entrants' Association] test, so we've covered a lot of distance and we've been putting everything into trying to make the car quicker over a long run.'

At first glance, the 2024 BRZ isn't easy to differentiate from prior iterations. There are more rounded front wing panels (fenders), compared to past versions, which had a more cut-out section around the headlights.

'In terms of aero parts, we changed the front wings and the end plates of the front splitter to increase front downforce, and to allow us to properly use the underfloor'

Masahiro Ozawa

Ozawa explains this was done to maximise front downforce, while further work was done on the car's 2.0-litre, four-cylinder boxer turbo engine, derived from the Subaru World Rally engines of years gone by.

'In terms of aero parts, we changed the front wing panels and the end plates of the front splitter to increase front downforce, and to allow us to properly use the underfloor,' continues Ozawa. 'Also, the engine has been modified to cope better with carbon-neutral fuel. We have taken measures to better control the temperature of the oil, and have modified the dimension of the pistons to reduce the amount of blow-by gas that escapes, and prevent oil dilution.'

Changing seasons

Despite the raft of changes, Subaru endured another difficult start to the season. In the first four races of 2024, Yamauchi and Iguchi only mustered a best finish of 15th, although the pair looked on course to at least grab a podium at Suzuka, only for a sudden loss of power to put the BRZ out of contention. Their car also posted the fastest lap at Okayama.

The BRZ has looked better on its Dunlops over a stint than it did last year, but it would be fair to say it has been hampered by the somewhat controversial new aggregate qualifying rules brought in for 2024 that require one set of tyres be used in both Q1 and Q2. That same set must then also be used for the start of the race – a format that could have almost been devised to benefit the small group of GTA-GT300 cars using Bridgestones.

'Dunlop and Michelin both have tyres that are easy to extract peak performance from for a single lap,' says Ozawa when asked how the qualifying format has impacted Subaru's chances, 'but with this year's format you end up using up the peak in Q1, and then it's a question of how much you have left for Q2. In that respect, I think it will be less regular to get pole positions with ease than in the past.'

Straight-line speed has been a further problem for the Subaru, making a good start close to the front of the grid crucial to any chance of race success, though recent BoP changes have helped here

Qualifying well has always been important for Subaru, given the characteristics of the BRZ. Across 2021 and 2022, the team scored exactly half of the poles on offer. With that kind of performance no longer realistic under the current rules, as well as BoP tweaks, trying to improve the car's 'raceability' has been another key focus for development.

Speed deficit

'Straight-line speed has never been our strong point, and I think again this year we are one of the slowest,' admits Ozawa. 'Overtaking in a straight line is therefore extremely tough for us. When we are starting further down the grid, and get caught up in the group, it's especially difficult.

'With the most recent BoP adjustments, though, it doesn't feel like we're so far off in terms of straight-line speed. Even if we can't pass other cars in a straight line, we can at least defend our position. For example, last year, even when we dropped out in Q1, we were still able to make some progress, so I feel like that's gone in the right direction. Of course, with our car's characteristics, it helps to start up front.'

The new qualifying rules are just one of a number of regulation changes that the GT300 teams are having to contend with this year. Among other adjustments, the minimum weight of the GT300 runners has been increased in the name of safety, with the BRZ now weighing in at 1236kg before BoP and success weight is added, marking a significant jump up from 1200kg last year.

This has not been universally welcomed by the drivers and teams, and concerns about how heavy the cars had become prompted the series organisers to impose a 50kg cap on success ballast mid-season, down from 80kg at the start of the year and 100kg last year.

'The weight has been increased, but this is the same for everybody, including the FIA GT3 cars,' says Ozawa. 'I don't think the performance will actually change that much, relatively speaking. Everything has been balanced in terms of performance [by the organisers], and we think it's a fair balance. I don't think it will make our lives any harder than last year.'

Renewable fuel

Carbon-neutral fuel (CNF) has been another major talking point in the Super GT paddock in the last 12 months. Last year, the series elected to introduce 100 per cent renewable fuel, provided by German firm, Haltermann Carless, for the GT500 class after extensive bench testing by Toyota, Nissan and Honda. Plans were then made for the GT300 cars to use the same product, but testing revealed oil dilution in the engines to be a major problem with the new fuel.

Super GT went back to the drawing board and asked Haltermann Carless to whip up a 50 per cent [carbon-neutral fuel] solution for 2024, which so far has not posed any issues

The BRZ was one of the worst affected by this tendency, and Subaru would undoubtedly have been relieved when plans to introduce CNF in GT300 in the middle of last season were shelved.

Super GT went back to the drawing board and asked Haltermann Carless to whip up a 50 per cent solution for 2024, which so far has not posed any issues, even for Subaru.

'The new CNF that the GTA has provided is really good,' says Ozawa. 'We can use it in almost the same way as regular [petrol] without any issues. With the 100 per cent fuel, though, evaporation was terrible. The base fuel was bad. The oil became more and more diluted, and the unburnt fuel would accumulate in the oil catch tank.

'With the 50 per cent fuel, the base of the fuel changed and this is much better. I think if they used 100 per cent fuel with the current

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base, there wouldn't be any issues. I think step by step they could increase the percentage.'

Equivalence between GTA-GT300 and FIA GT3 cars has been a near-constant source of contention in recent years, arguably even more so as the pendulum has shifted more towards the former in recent years.

In the last couple of seasons, Toyota-affiliated constructor, apr Racing, has built the GR86 GT, as well as the LC500h, the successor to the much-loved GT300 version of the Prius, while the Gainer team has also taken the plunge with a self-built version of the Nissan Z this year, bringing the number of GTA-GT300 models on the grid up to nine.

Meanwhile, there is just a single example of the 'Mother Chassis' Toyota 86, which uses a standard Dome tub paired with a Nissan V8 engine, while the number of FIA GT3 runners remains relatively healthy at 17 of the 27 runners on the grid.

Subaru's 2021 triumph ended a run of four years on the trot for teams with FIA GT3 cars winning titles. Since then, it's been one apiece, with the ageing Nissan GT-R NISMO GT3 coming out on top in 2022 with Kondo Racing (and the help of ex-GT500 ace, João Paulo de Oliveira) and then the apr-built Toyota GR Supra, now the oldest of the GTA-GT300 models stil in service, triumphing last year with the Saitama Green Brave squad.

'I feel like we've been getting closer and closer every year,' says Ozawa on the subject of balance between the two car types. 'In the past, the powerful GT3 cars and the 'JAF' cars that are good at cornering would have their own respective good tracks and bad tracks. At Autopolis, or Sugo, the JAF cars would be quicker, and in places where you need power, the GT3 cars were better. But now, it's not unusual to see either type of car winning at any track. So, I think it's better balanced now than when we won the title.'

The beauty of the way Super GT's rules are structured is that teams always have a chance to bounce back in the championship if things don't start off well. That said, it's clear the competition is much stronger now than it was even three years ago, with the general level of teams, cars and drivers having progressed significantly in that time.

Current season

At the halfway point of the current eight-round season, Super Formula team, Inging, led the GT300 standings, having shown great consistency with its Bridgestone-shod Toyota GR86 GT, even with heavy ballast. The arrival of new FIA GT3 models like the Ferrari 296 GT3, Lamborghini Huracán GT3 EVO2 and Aston Martin Vantage GT3 Evo has only served to raise the bar higher, with the latter two cars having already won races this year.

It's clear the competition is much stronger now than it was even three years ago, with the general level of teams, cars and drivers having progressed significantly in that time

Equally, the tyre war is much more vibrant in GT300 than it is in GT500, which has devolved into a near monopoly for Bridgestone. In the top class, the Japanese firm supplies 12 of the 15 cars following Michelin's withdrawal from GT500 at the end of last season. In GT300, though, Yokohama is the dominant supplier with 15 cars but has rivalry in four cars apiece from Bridgestone and Dunlop and three for Michelin.

All of that means Subaru has its work cut out to regain the title it achieved in 2021. Alongside its annual trip to the Nürburgring 24 Hours with a bespoke WRX STI racer, the BRZ programme in Super GT's second-tier class is the Japanese firm's main current motorsport activity, so you can bet Ozawa and the rest of the R&D Sport crew will be pulling out all the stops to try and close the gap to the frontrunners once again.

Since Subaru exited the WRC in 2008, it has focused its efforts primarily on domestic race series, with Super GT its flagship programme. A return to 2021 form would therefore be very welcome

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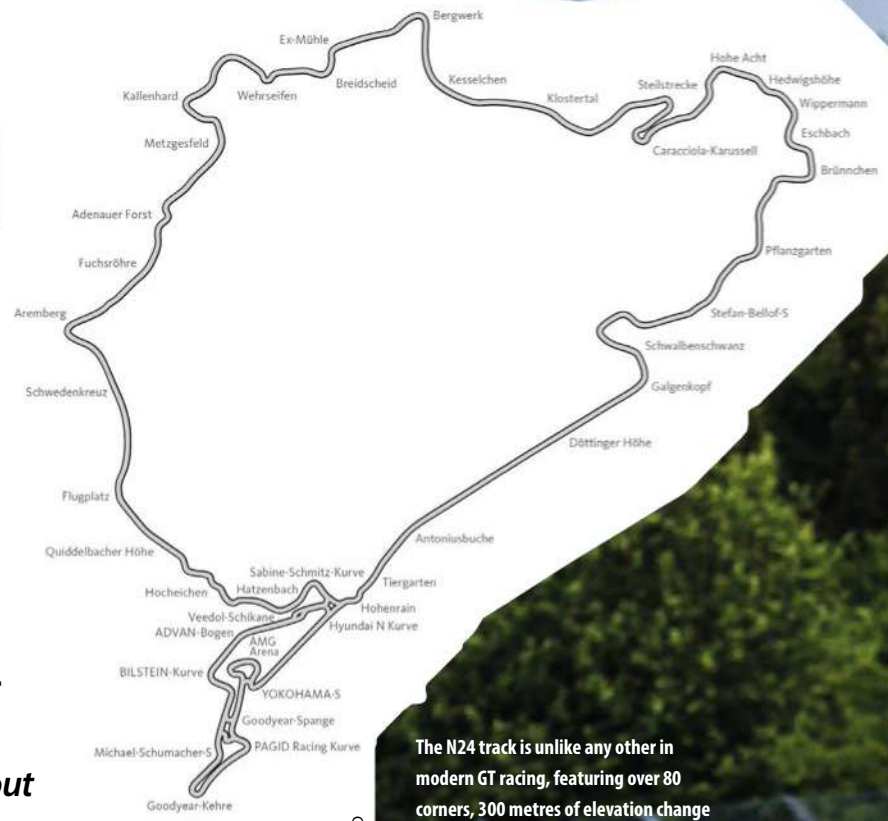


Graphic: Nürburgring

An endurance race like no other,* Racecar *joined the Falken GT3 squad to see what makes the Nürburgring 24 Hours stand out

By DANIEL LLOYD

The Nürburgring 24 Hours is one of the best-attended motorsport weekends in the world, attracting almost a quarter of a million fans to Germany's fabled Nordschleife, while at the same time retaining the traditions that give it a pleasingly accessible feel.

Interest is driven by the combination of a daunting 25.378km circuit with more than 80 turns, a 130-car grid with fabulous variety and huge speed differentials, and a festival crowd atmosphere full of bratwurst and beer. It is held on the Corpus Christi holiday weekend and the German fans take full advantage of their days off work to attend.

The 'N24', as it is often abbreviated to, is also the favourite race of many a top-level GT driver, even sitting above the 24-hour classics at Le Mans, Spa and Daytona, which may be considered more globally prestigious. Today's GT3 cars are so mechanically and aerodynamically stable that wheeling them around a regular racetrack is rather straightforward, but the Nordschleife washes out any complacency with sections that cause the cars to jump and slide. The Nürburgring's sheer size also means the weather can change several times during a lap, adding to the excitement.

Its tarmac ribbon, plastered in spectators' chalk graffiti like a Tour de France stage, winds through the dense forest of the Eifel region of Germany, flanked only by thin strips of slippery grass and metal safety barriers. There are several high-speed sections and mistakes are often punished with dramatic consequences. Here, the drivers' skills are tested, and exposed, like no other GT race.

The N24 also retains an 'old school' feel. The professional, sometimes factory-supported, teams running GT3 cars in the top SP9 class rub along with outfits racing more basic cars in slower categories on significantly smaller budgets. Fans can access the walkway between the team trucks and pit boxes, rubbing shoulders with the mechanics and angling for used tyres to keep as souvenirs.

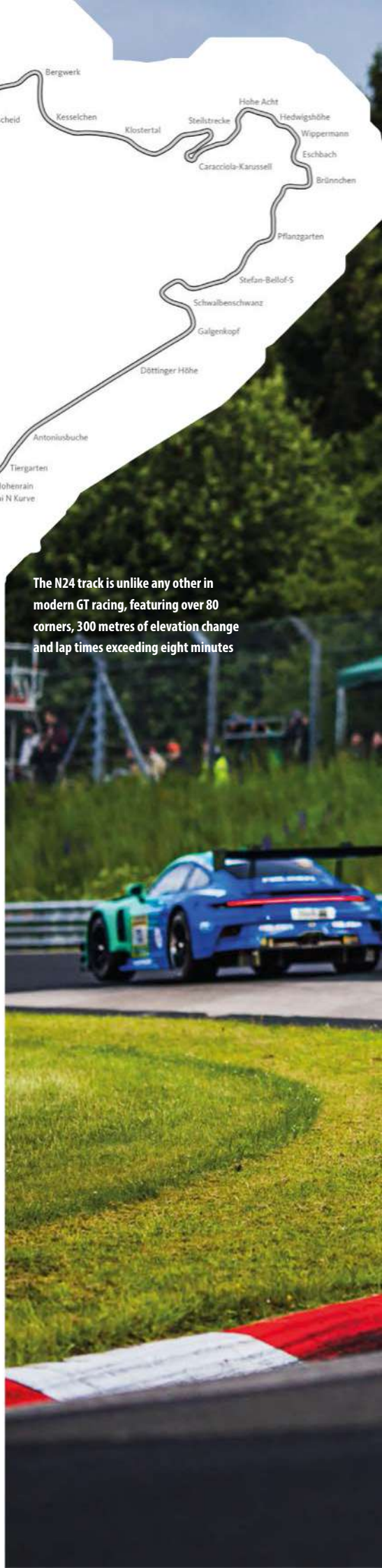
The big four

Despite that purity, it's a highly serious competition for victory between the 'big four' German car brands, whose rivalry into the GT3 era has tightened the margins and increased the professionalism. The level has risen in the last 10 years as teams continue to fine tune their cars' performance.

To understand what it takes to run the N24 in the top class, *Racecar* tagged along with one of the event's most experienced teams. Falken Motorsports has been competing in the race since 1999, initially running Nissan Skylines before moving on to top-level GT3 machinery.

Since 2011, the team has operated as a partnership between Japanese tyre supplier, Falken Tyre, and the Schnabl Engineering race team from Germany. Falken runs a pair of Porsche 911 GT3 Rs in SP9 with all-professional driving quartets.

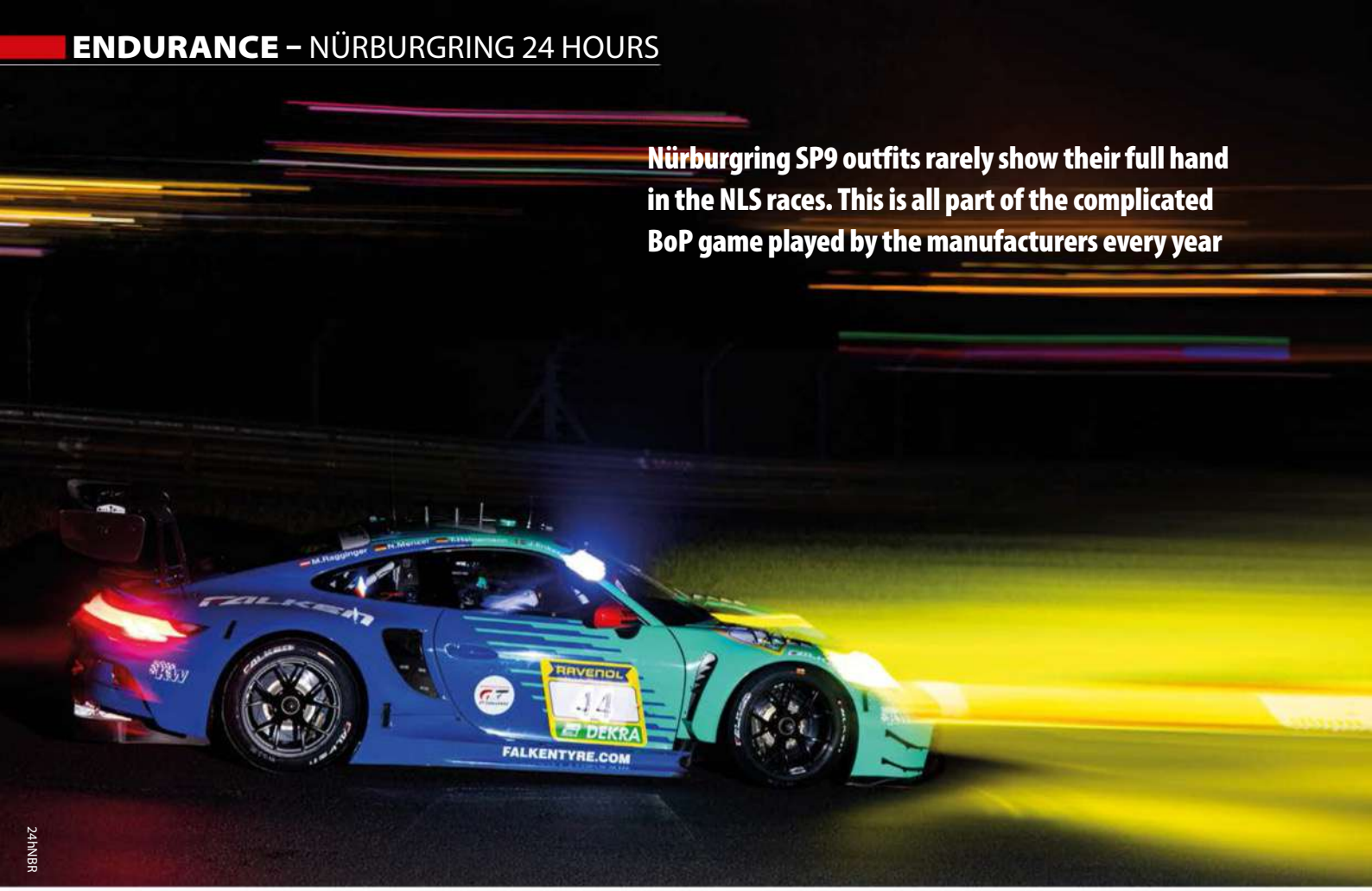
The Falken race programme is chiefly stimulated by the N24 permitting different tyre manufacturers, which is a rarity in GT3 racing nowadays. The other major 24-hour races at Le Mans and Spa both have sole GT3 suppliers that provide the same, single compound tyre to all teams.



The N24 track is unlike any other in modern GT racing, featuring over 80 corners, 300 metres of elevation change and lap times exceeding eight minutes

It's a highly serious competition for victory between the 'big four' German car brands, whose rivalry into the GT3 era has tightened the margins and increased the professionalism

Nürburgring SP9 outfits rarely show their full hand in the NLS races. This is all part of the complicated BoP game played by the manufacturers every year



24hNBR

After punctures last year, Falken and Michelin were allowed to bring a stronger tyre without eating into one of their available spec slots, provided there was no performance gain

At the Nürburgring, Falken and other companies do battle by developing their own rubber to gain an edge, and teams are free to choose from a range of compounds.

The open competition presents a good marketing opportunity, while different tyres produce different strenghts, weaknesses and compound crossover points. Consequently, Goodyear, Pirelli, Hankook, Yokohama and Michelin are all present in SP9, with the latter supplying 18 out of the 25 cars. Tyre choice is therefore a key part of the contest.

Rubber confidential

Although tyre development is encouraged at the Nürburgring, there are limits to what can be done. Each supplier is allocated four tyre specification slots that it can use over a defined homologation period. The current period started in 2022 and is due to expire after this year, although an extension of up to two years is being considered.

Each specification may include different constructions and compounds. So, as the suppliers make new tyre developments, they move on to the next specification slot. It's then up to the supplier how and when they use their specs within the homologation cycle. Consequently, if one rolls out all its permitted specs too early, it will be stuck with them until the homologation period changes.

Falken has so far developed two of its four permitted specs. The one used at this year's N24 includes soft and medium slicks, and soft and medium wets. Michelin, on the other hand, has soft, medium and hard slicks, along with a 'drying wet' – essentially an intermediate compound – and a full wet that can be cut further to form a 'monsoon' tyre. Pirelli also has three slick options, plus two wets.

The tyres are considered semi-confidential, so while suppliers can develop their own products, they must present them after the race for their competitors to buy.

Preparation races

After suffering punctures last year, the DMSB allowed Falken to develop a stronger tyre construction year that didn't use up one of its spec slots, provided it didn't aid performance (which caused some concern among other suppliers). In the build-up races, Falken found the changes yielded the required durability.

Unlike Le Mans and Spa, the N24 is not a round of a series, but there is a championship based at the Nürburgring called NLS that teams use to prepare for the N24. Falken won the NLS season opener and finished third in round two. It then won both races that constituted the N24 Qualifiers weekend, ensuring its cars would be fast tracked to the final qualifying shootout for the N24 pole held during the main event. Several other teams needed to slog it out in a prelimiary shootout to access the pole-deciding session.

Such strong results would normally be hugely encouraging for a team, but SP9 outfits play it smart and rarely show their full

Falken Tyres

Falken didn't get the opportunity to test its new wet tyre prior to the N24 weekend, meaning it had to learn on the fly in race conditions

Falken Tyres

Schnabl's team has been running the Falken operation at the Nürburgring since 2011. Its best result in that time is third in 2015

The huge grid means garages are cosy, especially for a two-car team with around 45 members. Sharing space is part of the event's charm

hand in NLS races. This is all part of the complicated BoP game played by the manufacturers every year.

'We showed what we can but, in my opinion, the others did not show what they can,' said Falken team principal, Sven Schnabl, before this year's event.

Scepticism of the BoP aside, Falken headed to the N24 with confidence in its car set-up. After the Qualifiers, the Falken cars underwent a full rebuild, with the engines and gearboxes being sent to Porsche.

'Everything is like new, and capable of doing another 50 hours,' noted Schnabl.

Into the event

In true N24 spirit, the Falken pit garage is shared with two other teams. The no.33 Porsche sits at the front of the garage and the no.44 Porsche at the rear, engineers working from a line of eight monitor stations. Each car is assigned a race engineer and a data engineer. There are also four tyre engineers from Japan who usually work in Super GT.

The fact a Super GT round took place on the same weekend emphasises the N24's importance to Falken. When we stop by on Friday (qualifying shootout day), the rear ends of both Porsches are being worked on as the team re-shims the cars' new differentials. The diff' on the 992-generation Porsche 911 GT3 R is a mechanical limited slip unit with an adjustable pre-load mechanism.

'It's a standard job, it looks worse than it is,' assures Schnabl, who says the decision to do the job on Friday morning, rather than evening, will let the team skip the pre-race warm-up session and give its mechanics a longer rest.

'We lose quite a lot of pre-load if they are brand new, so we are re-shimming the diffs.'

During the practice sessions that took place earlier, Falken ran multiple brake sets. It did this to bed in a second set it might use during the race if the originals become too worn. Teams are free to choose brake pad and suspension parts suppliers, so Falken uses Endless pads and KW Automotive's standard suspension for the Porsche, which gives the team five-way adjustability with the dampers.

'The car comes with KW, but you can have different settings inside that are tyre related or driver related,' explains Schnabl. 'As far as I know, we use something different to what others use. It is something that can make your car better compared to the others.'

Special set-up

The unique characteristics of the Nordschleife require a special set-up. According to Falken race engineer, Rodolphe Sauvageot, who works on Porsche 911 GT3 Rs in other series, the N24 car's ride height is 20mm higher than in GT World Challenge Europe, which races on more conventional, grand prix-style tracks.

'The aero is not working like on the GP tracks,' he says. 'We need to adapt, adding more aero [for the corners], but we also need low downforce for the long straight. In GT World Challenge, the car is low and set up for full performance. Here, performance is important, but there are so many other options. It's mainly about tyre choice.'

The suspension settings for the N24 are also markedly different to elsewhere.

'It's way softer than the [GTWC car],' adds Sauvageot. 'The Nordschleife has different grip. It's very narrow, like a street track. If you went for a GT World Challenge set-up here, it would be way too hard to handle, too edgy.

'Here, you need a bit more safety in the car. You cannot go at 105 per cent because we need to run for 24 hours.'

Because tyre choice is open, it is vital to understand the best time to switch compounds. This is even more difficult to gauge here than at other races due to the variable conditions. There is no need to double stint tyres because teams are allocated 29 sets for the event.

Compound interest

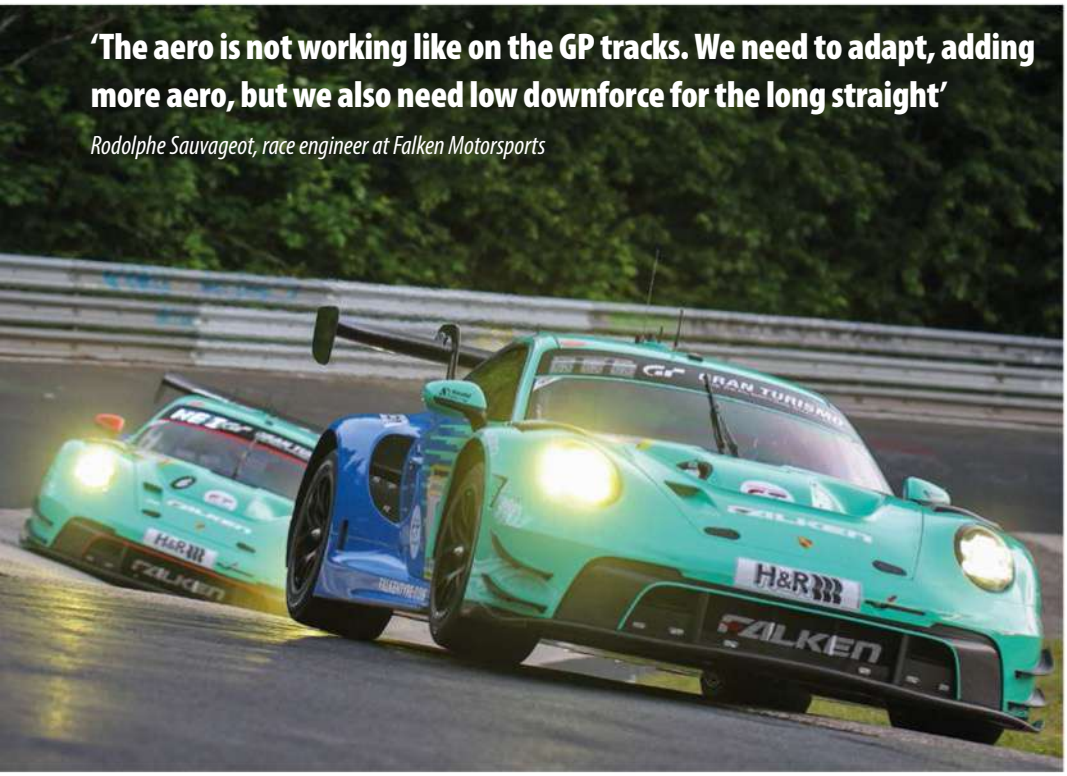
'The Nürburgring is way different from a normal track,' adds Yoshi Yasuda, manager of the motorsport development group at Falken Tyres. 'It's huge, so the tyre performance window has to be very large. Also, other tyre manufacturers can buy other manufacturers' tyres, so you have to be a bit careful about what kind of technology you're going to put in.

'Basically, it's about the compound. Construction-wise, it's not very special. We just design a construction for the specific car, and that's not any different from other tracks.'

'The aero is not working like on the GP tracks. We need to adapt, adding more aero, but we also need low downforce for the long straight'

Rodolphe Sauvageot, race engineer at Falken Motorsports

Falken Tyres



The compression changes experienced over the course of a lap require a much higher ride height than is seen in other GT3 races

Falken's slick tyre compound range covers dry track conditions up to 60degC. The crossover point between soft and medium is understood to be in the mid-to-high 20s, but that isn't a factor this year because temperatures aren't high enough for the medium to be considered. As with other suppliers, Falken provides a recommended tyre pressure window, which the drivers say has been improved upon since 2023.

'With this car, the balance changes depending on the amount of fuel because the tank is in the front,' adds Yasuda. 'We're trying to compensate that by controlling the pressure, so that the front becomes lower and lower throughout the stint.'

Falken uses the N24 practice sessions to hone its race set-up and obtain valuable mileage on its new, unused rain tyre. All eight drivers are cycled through the cars, which is vital since date clashes with NLS rounds mean some have enjoyed more Nordschleife seat time than others. Practice also allows the drivers to familiarise themselves with any track changes. Most notably for this year, the section from Aremberg to Adenauer Forst has been re-paved, with a kerb on approach to the latter corner sequence raised.

'We cannot go on [that kerb] any more,' reports Martin Ragginger, driver of the no.44 Porsche and an N24 stalwart. 'Otherwise, you will break the suspension, or the car jumps away and you end up in the barriers. You could sometimes squeeze in there to overtake over the kerb, but this is now trickier.'

Pole importance

The team appears relaxed on Friday, but the qualifying shootout doesn't go as planned. Klaus Bachler produces a lap time of 8m13.692s in the no.33 car to go 10th quickest. Nico Menzel, who set the no.44 car's best lap during each of the three practice sessions, only manages an 8m15.208s, while the pole time is an 8m10.992s set by the BMW M4 GT3 of Dan Harper. The gaps may seem large, but Bachler's deficit translates to one tenth of a second per kilometre.

When asked where the Falken cars are lacking pace, Menzel reports: 'It's straight-line performance, it's power, it's grip. A bit of everything to be honest. It's not totally understandable why it didn't work out for us because we had better runs in practice, and especially in NLS and the quali' races.'

The best of the Porsches comes from Manthey, the N24's joint most successful team with seven wins. After Manthey qualifies second, all Porsches are given a series of BoP changes: 10kg weight increase, a 1.5mm smaller engine air restrictor diameter and a one-degree reduction in maximum rear wing angle. The Porsche teams aren't pleased, not least because it means they now need to go through technical checks again on race day.

Falken Tyres

The Falken Motorsports data hub in the garage is supported by Porsche's central 'battle room' upstairs that serves all its SP9 teams

Usually, pole for a 24-hour race means little more than a nice headline before the endurance test starts. But at the N24, it carries greater importance because of how the race is run. For example, there are no safety cars. So, when an incident occurs, race control initiates different slow zones depending on the severity, up to a so-called 'Code 60' where cars must not exceed 60km/h. It's therefore beneficial to lead from the front, to escape incidents that may cause Code 60s behind.

The lack of safety cars means that, when an incident does occur, the gaps between the field are not re-set. Instead, gaps are changed through lap time and, occasionally, luck, based on when and where the Code 60s happen to fall. Generally speaking, the fortune and misfortune of Code 60s balance each other out, so the race feels more organic than Le Mans, Spa or Daytona, where gaps can be restored to zero by a safety car.

Strategy options are, however, very limited due to a minimum pit stop time, which means there is little to gain through slick pit work. Pit strategy only comes into play at the final round of stops. This is because the minimum pit stop time is tied to the number of laps in a car's stint, so the shorter the penultimate stint, the shorter the final stop can be.

'The goal is to extend the stint as long as possible and try to find the best spot at the end of the race, because then you can gain time in the pit,' says Sebastian Golz, project manager on the Porsche 911 GT3 R.

The lack of safety cars means that, when an incident does occur, the gaps between the field are not re-set. Instead, gaps are earned through lap time and, occasionally, luck

The rear wing on the Porsche 911 GT3 R is adjustable, although each GT3 manufacturer is given a maximum permitted wing angle to use

'This would be too easy if there was not such changeable conditions, traffic and Code 60s. The Code 60s can give you possibilities to change strategy. Maybe pit the car one or two laps earlier, do a refill and count on the Code 60 being over when you go out. You can gain a lot of seconds that way.'

Changeable conditions

The key topic on Saturday, race day, is the weather, which is normal at the Nürburgring. Last year's race was remarkable for being held in completely dry conditions, but none of the teams are expecting lightning to strike twice. Sure enough, as the clock ticks towards the 4pm race start, light rain starts falling.

Falken opts for soft slick tyres that have been modified with shallow cuts to dissipate some of the surface water and generate grip. Other teams, including the pole-sitting BMW outfit, opt for slicks, but that turns out to be the wrong choice as its car pits after one lap for more appropriate tyres.

The first hour sees Alessio Picariello and Menzel initially stay out of trouble. As the stint progresses, the rain eases and dry lines start to emerge, encouraging drivers to push harder. At one stage, it looks uncomfortable between the two Falken Porsches as Menzel overtakes Picariello in the no.33 car on the inside at Schwedenkreuz – a fast left-hander

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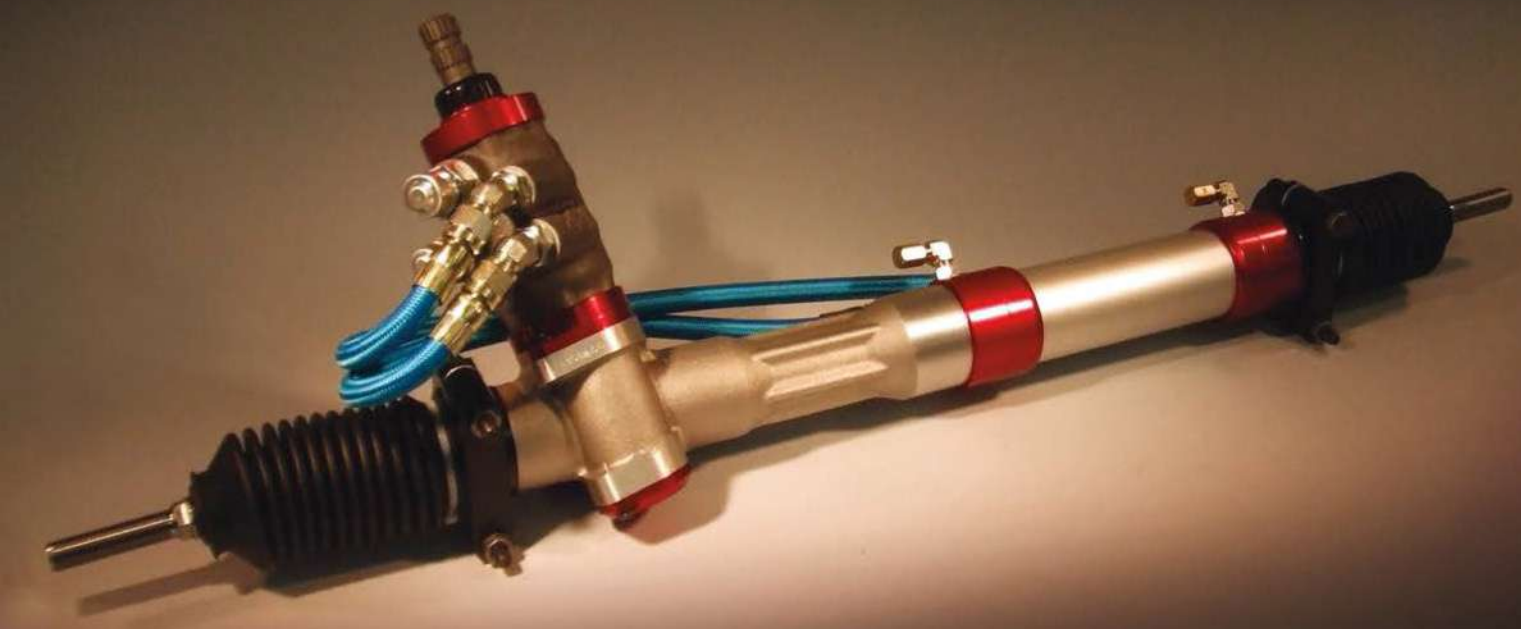

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taken at 250km/h – only to then slide into the gravel when he overshoots the next turn. However, Menzel dusts himself down and goes on to pass Picariello at the same spot on the next lap; the Falken drivers are entrusted to race each other, within reason.

On lap six, both Porsches pit as their cut slicks are worn from the dried-out surface.

They have weathered the storm on this occasion, since most other SP9 front runners have also completed six laps. Menzel and Picariello continue in 11th and 15th for the next stint, and things remain stable as they hand over to Joel Eriksson and Sven Müller respectively after almost two hours. Müller gains a handful of spots and rises to 12th while Eriksson breaches the top 10, although his no.44 Porsche is still two and a half minutes off the leading BMW (which then crashes out after contact with a slower car).

Rain returns in the fifth hour, at which point Tim Heinemann has taken over the no.44 and Julien Andlauer the no.33. It starts as spots, but is soon enough to compromise grip, as Heinemann discovers when he goes straight on at turn one and into the gravel. Fortunately, the Falken cars are near the end of their stints but, surprisingly, they remain on slicks instead of taking wets.

A spin for Andlauer exiting the chicane draws some concerned glances from the engineers as they wonder if they made the wrong call. The timing screens soon give them the answer, as the few cars that remained on slicks (the Manthey Porsche included) are reeled in by those out on wets.

Having already lost substantial time and positions, Falken calls in both cars after just five laps. New drivers and tyres are installed, this time the softer of the wet options. Meanwhile, Falken's race engineers observe onboard video from the car 20 seconds ahead of theirs to gauge how the track conditions are evolving. Weather radars are also displayed in the garage and Porsche provides its own forecast from an upstairs 'battle room' to help its customer teams make their calls. The stint on soft wets only lasts four laps as both cars pit early again, this time for a change to slicks. Mechanics rush out to the tyre tent and return with stacks of new rubber. Both cars would have jumped to slicks sooner than this, but the minimum pit stop time after a stint of three laps is not long enough to cover a four-corner tyre change. It is deemed less wasteful to keep the overheating wet tyres on for another lap than to pit for longer than needed.

'The race that happened was never boring. You had to be spot on. You had to watch the weather. You had to make sure you had the right tyres on at the right time. It was never easy'

Sven Schnabl, team principal at Falken Motorsports

Fog stops play

The drama surrounding the difficult tyre calls is making for a thrilling race as darkness falls. Even for experienced teams, the unstable Nürburgring weather puts up a great fight, and often wins. Consequently, a selection of tyre compounds can be seen along the back of the garages, and it's exciting to try and figure out what the teams are using.

This is made harder by the fact the Michelin intermediate and full wet look identical, so it's impossible to tell what a car is running purely by sight: one needs to ask an engineer to check the tyre's barcode.

Falken Tyres

The sight that greeted competitors when they returned to the track on Sunday morning after racing was postponed just before midnight. This year's N24 was the shortest to date, undercutting the 2021 winning distance by 228km

However, there is another variable approaching that will soon quash the tyre choice shenanigans. Fog has interrupted several N24 editions over the years and locals know that, once it arrives, it beds in for the night. Sure enough, in the eighth hour, at 11.30pm, race control throws a red flag. Further news won't come until 7am.

This gives some respite to the tired engineers, who started the race drained from a long event build-up, but that rest doesn't come until they have checked over the cars. Some teams take the opportunity to fit new brake discs and pads, but Falken decides not to in case this causes the cars' feel to change when racing resumes.

The wing angles are tweaked a couple of degrees, and the no.44 car receives an anti-roll bar adjustment, but otherwise both Porsches are left alone.

Muted conclusion

Unfortunately, the fog still hasn't dissipated by Sunday morning, and it quickly becomes clear that racing won't be possible until the afternoon. Eventually, though, the fog does lift enough for the cars to line up on the grid for five formation laps. Some teams choose to pit during these laps, Falken being one of them with Porsche no.44. This is the first time the team has split its cars' strategies.

'We decided that if they bring [the pace car] in after lap five and we pit under it, we can go back into the queue,' explains Schnabl. 'If you do your pit stop under race pace, the others are gone by two minutes.'

Stopping drops the no.44 Porsche down to 11th, while the no.33 stays out until the organisers call an end to the race with just under an hour left on the clock. The decision to throw an early chequered flag causes some consternation among those teams that had pitted, because the final result would have been different in their favour if a red flag had been shown instead. One of the BMW outfits goes as far as appealing the outcome on these grounds, albeit unsuccessfully.

Despite the regulatory confusion, Falken comes away with its 11th consecutive top ten finish at this gruelling event. There has been less than nine hours of racing, but the engineers are visibly taxed from the mental assault of turbulent weather conditions.

There are mixed feelings in the garage afterwards, since the teal and blue Porsches weren't the fastest SP9 cars outright and not all tyre calls went smoothly. Nonetheless, the cars and drivers had a largely trouble-free run.

'The race that happened was never boring,' concludes Schnabl. 'You had to be spot on. You had to watch the weather. You had to make sure you had the right tyres on at the right time. It was never easy.'

That's the challenge, and the allure, of the Nürburgring 24 Hours in a nutshell.

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The new(ey) guy

Pierre Waché has been at Red Bull for a decade and technical director for six years, although his role has often been overshadowed. With Adrian Newey now leaving, he tells Racecar Engineering *about his extraordinary journey to the top of F1*

Interview by Christian Menath

Christian Menath: You have a very interesting background. Most of the people in the paddock are here because they *really* wanted to be in Formula 1, but not you.
Pierre Waché: No, clearly not! It wasn't even on my radar to begin with. My family has a scientific background in medicine. They were all doctors. I did my PhD in fluid mechanics and specialised in biomechanics, looking at the effect of blood flow on the radial cells around the vessel.

CM: Did you only choose that path because you grew up this way, or were you genuinely interested in the subject?
PW: I didn't know at the time. The opportunity arose when I was doing my PhD. It wasn't that I liked those topics more than others, I just liked the challenge, and I chose to accept it.

CM: Studying usually comes with a goal of what you want to do later. What was yours?
PW: My goal at the time was to become an academic researcher. I had a proposal for it, but I had to do military service at the time. I was one of the last people in France who had to do that.

There was an opportunity to do research work abroad instead of military service, and I had an offer to work at Georgia Institute of Technology in the United States as a postdoctoral researcher, but I met my wife and decided against it. I wanted to stay in France with her, so I did my military service in Paris and after that my life changed.

CM: Because you went to the tyre manufacturer, Michelin? How did that change of direction come about?
PW: After my military service, I was looking for a job. I couldn't do academic research in France because I didn't do postdoc research. That's why I was looking for an R&D position in industry. I'm not a Parisian and I like the countryside, so I looked for a job outside the city. Michelin was located near the office where I did my military service, so I applied there and got the job.

CM: So you had nothing to do with motorsport until then?
PW: Don't get me wrong, I've loved motorsport and sport in general since I was a teenager. I love the competitive aspect,

It was all about the interaction between the ground and rubber… I loved working on that challenge, and never stopped doing it after

Though the competitive element of motorsport was always of interest to Waché, he never set out to work in the industry, but a research job at Michelin opened the door and he's never looked back

but I never thought I would be [working] there. Even when I started at Michelin, I didn't want to be in Formula 1, the purpose was to research aquaplaning because that's where I came from. I said that I could help with that and ended up getting a job in Formula 1.

It was all about the interaction between the ground and rubber, and that was similar to what I had done in the past. I loved working on that challenge, and never stopped doing it after.

CM: Do you still understand what happens between the asphalt and the tyres? It seems a bit more complicated with today's Pirellis...
PW: I will not say I completely understand it; it's at the limit of what we know. With the information we have, it's better to have more knowledge than less, but we are still missing a few aspects.

CM: What exactly did you do at Michelin?
PW: I was there for seven years. In the first few years I was in research and developed models to anticipate the mechanical grip between rubber and tarmac and to give a direction for rubber development for better grip in dry conditions. That was more on the tyre side. Later, I was on the car side, looking at how the car works with the tyre. I was on site for testing, but I was never at the track otherwise. I focused on research and development.

CM: When Michelin left Formula 1 in 2006, you went to work for BMW Sauber. How did that come about?
PW: [Former Michelin engineer] Loïc Serra went to BMW before me and then attracted me. I found the challenge very interesting. I could have stayed with Michelin – it was a fantastic company, I loved it and they gave me the opportunity to continue there – but Loïc won me over. He is a very convincing personality, so I went to BMW. That was a very nice experience.

CM: You took on an overarching role for the first time at Sauber, having previously focused on an area. How did that work out?
PW: I did tyre engineering and vehicle dynamics there. I think everyone has to start the same way, whichever team you work for. You start with what you are very good at, where you think you know more than the

After a fruitful eight years at BMW Sauber, Waché received a call asking him to join the Red Bull team as chief engineer focusing on vehicle performance. He's been there ever since

Waché recalls his first impressions of Adrian Newey (below, left) as being a very good aerodynamicist and extremely competitive, but also very open minded, and puts a lot of his success down to that latter trait

When you're dealing with tyres, the overlap with driving dynamics and aerodynamics is quite big. The tyres are the only thing that touches the ground, so they generate the performance of the car

others in some areas. I'm not sure I'm better at it than others, but you're an expert in that area. Then you look at the interaction of that area with the rest.

When you're dealing with tyres, the overlap with driving dynamics and aerodynamics is quite big. The tyres are the only thing that touches the ground, so they generate the performance of the car.

Then you interact with aerodynamics because you look at how they behave in the wind tunnel and how the shape changes in CFD. Vehicle dynamics at BMW was a continuation of what I had done at Michelin.

In France, we study in a more general aspect, we are not as specialised as in some other countries. On the one hand, this is a weakness because you can't plug and play to do a job. On the other hand, you have a bigger toolbox, but you don't yet know how to use all the tools.

It helps me to communicate, and it has given me the opportunity to grow in this system, and to have an overview. That's how I got the opportunities. I was patient. The problem I see now is people who are very good technically, but are very impatient to get to the top. You have to be patient.

CM: For many, extreme specialisation is probably a problem. If you start at a car manufacturer today, you specialise in an indicator lever, but that has nothing to do with the car itself.

PW: It could be frustrating, but you still have a very important part to play, because if the indicator doesn't work, the system doesn't work. You have to find the motivation in that. I think all jobs in the company are very important, but sometimes people don't realise how important they are.

CM: BMW withdrew from Formula 1 at the end of the 2009 season and Sauber subsequently became a customer team. How did you find that period of transition?

PW: It was a difficult time for lots of people because we reduced the number of employees. But I always try to see the positive in everything, and it gave some people more opportunities. When you have fewer people, you have to expand your area of knowledge, so that was a very good experience for myself.

For me to leave a job, very bad things have to happen, or there has to be a great opportunity, or a great motivation. I usually stay where I am, I'm quite happy with that.

CM: So what was the motivation for you to move to Red Bull in 2013?

PW: Adrian [Newey] contacted me. Or rather, someone contacted me on Adrian's behalf and said they wanted me to join the team. The challenge of working with him in a world champion team was so great for me, even though I knew we would never be world champions at Sauber in the situation we were in at the time. Even if we did a good job, we would finish fourth, fifth or sixth.

It would have been difficult to take the next step, but I wanted to see what is needed to do that. It was also a massive challenge for me to work with him.

CM: Why was it such a great challenge?

PW: With Adrian, and with the world champion team, when you don't know what you don't know, and you want to see if you're good enough for the next level. That was the challenge, and mainly what motivated me.

Waché was promoted to technical director at Red Bull in 2018 when the team was going through a difficult time, but maintains that lessons learnt then helped the team toward its recent world championship successes

CM: What image did you have of Adrian before you started working with him?
PW: That he was a very good aerodynamicist, and a very famous person. I didn't think about it more than that as I didn't know him. If you're not in the English bubble, you don't know the people.

CM: How has your view of Adrian changed over the years?
PW: I was surprised by his open-minded approach and his competitiveness. If you know him, you know that he is a very, very competitive person. When you get older, and are very experienced, you usually have an answer. I see this with my parents, and I'm the same. The older you get, the more pronounced the tendency to stick with what you know. That's a fact.

Adrian, on the other hand, can change his mind. I think that's the reason why he's been at the top for so long.

CM: How did the structure of the technical team at Red Bull develop over the years?
PW: It depended on how the different people were involved. When I started at Red Bull, Adrian was clearly working full time. The other technical leaders were Peter Prodromou, Rob Marshall and Mark Ellis. That was the environment I came into.

When Mark Ellis and Peter Prodromou left [for Mercedes and McLaren], new people and new structures came in. Adrian reduced his involvement in Formula 1 after 2014, and he explained the reasons for that himself at the time. We then organised ourselves differently and things evolved from there. It's natural.

CM: When you joined Red Bull, the team's phenomenal success quickly disappeared. After four consecutive world titles, the wins dried up as it struggled with the Renault power unit. How did you cope with that?
PW: You have to be resilient in this business. In every part of this job, people work at their maximum every day, and then you can have a crash in Q1… So, even if what you're doing doesn't help you win in the end, it helps you make progress.

What we had going on in this phase helped us to win in 2021, 2022 and 2023. I would say that the team develops even better in difficult times.

CM: You became technical director at Red Bull in 2018. What changed for you as a result?
PW: The change was I had to deal more with other aspects of the car than I had previously felt comfortable with. It doesn't mean I was doing a good job, but that I was more comfortable.

It's quite a difficult challenge, especially with people who had been there for a long time, but I tried not to be a control freak.

To be honest, I don't know if I did a particularly good job in 2018 and 2019. I first had to learn how to interact with others. Some of those people had been there a long time, and my relationship with them went from being their colleague to becoming their boss. That was difficult for me, but when people left and new ones came in, it was maybe easier for me to interact with them.

CM: Adrian is now leaving the team completely. To what extent do you need to re-structure because of that?
PW: We're not re-structuring at the moment. Don't get me wrong, we will miss him. Of course, you will miss someone with so much

We are here to take risks, and this team takes more risks than anyone else… We are never on the defensive, we are always on the attack. That's a fantastic mentality

'We are not happy by winning, we are unhappy by losing. That's quite different.'

Waché credits much of Red Bull's success to team principal, Christian Horner, more specifically the way he and Newey built the squad up with a race team mentality, never blaming anyone for failure and protecting the whole team at all costs

experience, and with such an overview of the entire car. You know, it's something that is not missing, but it's something outside of us now.

We have a good structure that can get the job done without him. With or without him, the team is alive. If we realise in the future that we are missing something in one area, we will re-structure.

As in any system, you try to evolve in order to progress. What you are doing is never taken for granted.

CM: Do you feel like you have more pressure on you now?
PW: No. I have the same feelings and the same pressure now as before. If we fail, I have the same feelings and the same responsibility as before. If we failed before, I felt it was my responsibility, whether Adrian was there or not.

Maybe there's more pressure on me from the outside now because I'm in the media a bit more. Maybe it's more pressure for my family, but nothing changes for me.

CM: Why is Red Bull the most successful team of the last 15 years?
PW: This team was built by Christian [Horner] and Adrian around the race team mentality. You have to recognise that they have done a fantastic job with that. We are a racing team, not a corporate system.

I don't judge how other people work, but we have a crazy mentality: we are not happy by winning, we are unhappy by losing. That's quite different.

Like-minded people and lots of details make a winning team. That also means you must accept the loss. When you're in a difficult time, you have to see how you can move on. This team never, ever blames the team.

The way Christian protects the team from the outside is very good for the factory, and the team in general. You will never hear him say that the team is doing a bad job because they didn't finish on pole. He *never* says that, he protects us. Even if we sometimes do a bad job, we just know that we can do better. It also helps that we have a calm environment and can solve problems. That helps you to keep people and develop yourself.

CM: Is that the reason you can take risks on every single part, the strategy and so on?
PW: Yes, because of two things: the protection we enjoy from Christian and the company. The mentality of the company is very good in this respect.

And then there's the racing mentality. We are here to take risks, and this team takes more risks than anyone else. That's how we race, and you can see that in the strategy. We are never on the defensive, we are always on the attack. That's a fantastic mentality.

CM: What would you say has been the biggest challenge in your career to date?
PW: My arrival at Red Bull. I wanted to show that I could also make a difference in a winning team. That was very challenging for me, personally.

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Racecar *visited Caterham's new factory to talk about its successful motorsport programme, and the much loved Seven that's at the heart of it*

By MIKE BRESLIN

Seven heaven

There is a broad and very smart balcony area called 'The Terrace' that overlooks the factory floor at Caterham's brand new manufacturing facility in Dartford, Kent. From here, visitors have a fine view of all the activity below, and it's a scene that will be very familiar to many readers of this magazine. For rather than a production line with whirring robots, this car factory is more like a race shop, with individual bays where skilled technicians build the cars. Consequently, it feels more like visiting a racing team, albeit a very large one, than a motor manufacturer.

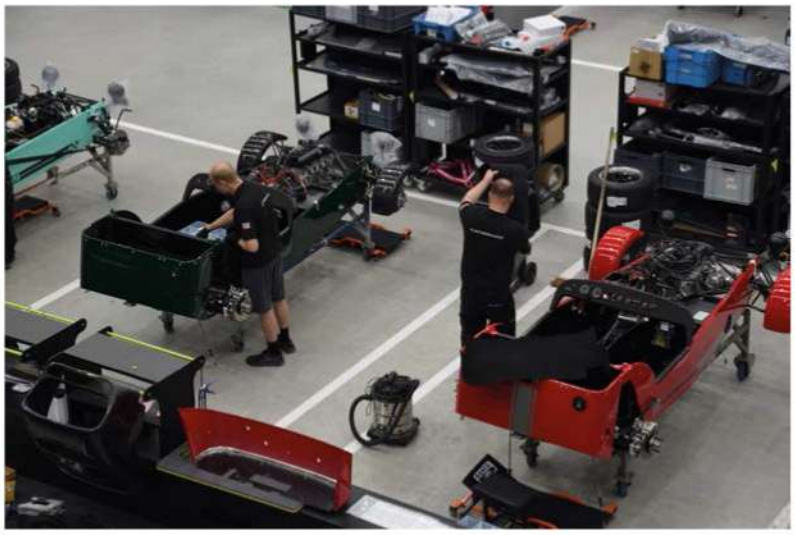
Perhaps this should not be surprising, for motorsport is at the very heart of this British sports car company. Indeed, Caterham Motorsport now runs five single-make championships in the UK, one of which has likely introduced more new competitors into racing than any other over the past couple of decades. On top of this, there are other series for its cars that are active across the world (the French and Portuguese championships are particularly healthy), and let's not forget – though some might prefer to – that the Caterham name also graced Formula 1 for a short time.

What is most telling, though, is that the Caterham racecars are assembled alongside the road cars as part of the same build process. This probably says more about the latter than the former, but surely illustrates the two are fundamentally intertwined in terms of technical philosophy.

The Lotus position

This has always been the case, for the car at the heart of Caterham is the Seven, a vehicle whose lineage can be directly traced back to the Lotus Seven of 1957, a car designed with club racing firmly in mind.

Caterham is one of the most popular cars on the UK race scene, and the firm currently runs five championships from its new Dartford factory, including 310R (main pic)



Each Caterham Seven, including the racecars, is built by a single person in one of the factory's 33 bays. The technicians that work in them are expected to build at least two cars a month

Chassis are spaceframes with aluminium impact protection panels sandwiching an aluminium honeycomb structure. The rollcages for the racecar versions are bolted in during the build process

Caterham Cars, then a Lotus dealer, bought the rights to build the Seven from Lotus in 1973 and it remained an independent company until it was purchased by the Team Lotus Formula 1 outfit – the Tony Fernandes version – in 2011, so it could use the name in F1 (see box out on p42). There have been other owners since, but Caterham is now under the umbrella of Japanese company, VT Holdings.

The most visible benefit VT Holdings has brought is the recent move to a new, 54,000ft. sq facility in Rennie Drive, Dartford.
A £5m investment, the factory has initially been leased for 12 years. This gives Caterham the capacity to build around 750 of its Sevens a year – up from approximately 500 before the move – of which about 15 per cent of the total built are racecars.

The company started out in Caterham, Surrey, before relocating to Dartford in 1987. The Kennet Road factory operated for 36 years until the new site opened this year. Some of its 130 employees work in the individual bays in which all Caterhams are built, with a single technician responsible for each car. Every completed Caterham bears a small plaque proclaiming who assembled it, which instils pride and, because of that, an additional layer of quality control. It's an approach to car building that Caterham is very proud of, but one that is also necessary because of the wide range of Sevens it sells.

'At one point, someone tried to put a production line in,' Caterham CEO, Bob Laishley, recalls. 'It didn't work because the variation in our cars is so huge. If we take a 170, it takes 30-40 hours to put together, whereas a 620 takes 60-70 hours. So, as soon as you've got a 620 in a production line, every 170 is costing you the same amount of money to build as a 620. It just doesn't work.

'What you're seeing here is 33 production bays. Each of the bays has one car in it, and it's built from beginning to end by one person. That's the ethos of the business: all our cars are individually built.'

Chassis facility

There is one very significant element of the Seven that is not manufactured at the current Dartford facility, though. 'We don't build our chassis here,' Laishley explains. 'We've got another facility in Wiltshire, which is Caterham Westbury. They put our chassis together.

'We made the conscious decision not to integrate that into this building, because it's a very skilful operation and relies 100 per cent on the skills and dedication of that team. The chances of getting all of them to move from Westbury to here would have been virtually zero. So, for the cost of transportation once a week for 12-15 chassis, it wasn't worth the investment in moving, and certainly wasn't worth the risk of losing all that skill.'

All Caterham chassis are spaceframes, reinforced with outer and inner aluminium panels that sandwich an aluminium honeycomb. The racecars, and other track-focused Caterhams, are also fitted with rollcages, bolted in place during their build.

Chassis arrive unpainted to an area called Drill Up, where various holes are made based on whether it's to be a right-hand or left-hand-drive car. These holes are for fuel tank position and exhaust exits, which depend on the type of engine being fitted.

Power delivery

That brings us neatly to the power units. Caterham Sevens have used a variety of engines over the years, including the Vauxhall Redtop and the Rover K Series, but for close to two decades now Ford's Sigma and Duratec engines have been the power units of choice (although the company also markets a turbocharged, 660cc Suzuki Jimny-engined car, of which more later). There is, however, a supply problem brewing with regard to the Ford units.

'Ford has stopped producing the Duratec engine we use, but we have secured three years' worth of production,' says Laishley. 'They're all here in the UK now, so we have no supply concerns in the short term with that engine. We're now investigating what engine we put in the car after that.

'The good news is there are OEMs planning to produce IC engines well into the next decade. If they're putting them in new cars until the middle of the next decade, that means they'll be servicing them until 2045.

'So, in terms of the supply of an IC engine, there's no issue. The challenge is finding one that will fit, because we can't change the shape of the car. Modern engines are becoming taller, because they're moving to shorter blocks with longer stroke to get more packaging space for a hybrid system in a transverse layout.

'There are [suitable] engines out there, and we are looking at them. We're at the stage of layout with two or three different options now, so hopefully we can choose that soon.'

Ford's Duratec and Sigma engines have long been the powerplant of choice for Caterham, but they are no longer in production. There is no immediate crisis as Caterham has plenty in stock and is close to finding a suitable replacement

'The good news is there are OEMs planning to produce IC engines well into the next decade… that means they'll be servicing them until 2045'

Bob Laishley, CEO at Caterham

'What we want to achieve with each level is that you get out and say, that feels faster, straight away. To feel the car is giving you something more'

Simon Lambert, motorsport director and head of customer engagement at Caterham

With high drag aero that promotes slipstreaming, Caterhams racing are always exciting to watch. The 270Rs (shown) run without windscreens and lights and with a wider track front suspension

As with any road car producer in the current climate, Caterham also has to consider more fundamental changes that may come in the future.

'We started to look at an EV Seven,' says Laishley. 'We built a couple of vehicles last year and proved to ourselves we can build a Seven with a similar weight and performance of an IC engine version. It was about 70-80kg heavier, but with the same performance, so it works. There's just no organic demand for an EV Seven at all, it would entirely be driven by legislation.'

Symbiotic support

As mentioned, the production of Caterham racecars is embedded in the road car build process, and this symbiotic relationship continues at the track. Some of the technicians that assemble cars during the week also volunteer to help with the works-run race championships at the weekend, providing technical support to those series that do not allow professional teams, namely the Academy and Roadsport categories.

There is also a busy motorsport department, headed up by Simon Lambert, who describes himself as motorsport director and head of customer engagement. He oversees five championships, but it should be noted there are independent Caterham championships in the UK, too – such as Graduates – and a great many Caterham racecars out in other series. In fact, there are probably more Caterhams racing in Britain than any other car, although the Mazda MX-5 might conceivably rival it in terms of numbers.

Part of the reason for the very large footprint on the UK race scene is the success of the entry level Caterham Academy. Lambert has a close personal, and professional, attachment to this championship.

To keep costs under control, carbon fibre is not used on the bodywork, even of the higher spec racecars. All models can come in pretty much any colour you desire as the factory is equipped with its own in-house paint shop

The Caterham Academy has introduced over 1300 new drivers to motor racing since it began in 1995 and remains a good source of revenue for the manufacturer, with 50-56 cars sold each year for this novices-only championship

'I was Academy driver number one, the first to sign up,' he says. 'I came second overall, and am full of excuses for that, and will forever be disappointed, but I did win my very first race, and the Academy's first race.'

Academy action

It's not at all unusual for the victor in a season-opening Academy encounter to be a first-time winner, as the series is strictly for novice racers. It's done a good job of attracting them too, with over 1300 drivers going through the championship since its inception in 1995. That also means over 1300 cars sold, and the Academy continues to be a good earner for Caterham, with between 50 and 56 new cars shifted every year just for these championships.

Note the plural there, because with over 50 cars each year the grids do need to be split into two separate series. Yet, interestingly, there is no run-off to find an overall champion. They are simply treated as separate entities so, according to Lambert, neither series feels devalued in any way.

Helping to keep the playing field as level as possible, there is no professional support allowed in the Academy. 'You can't come along with a paid person to help,' confirms Lambert. 'People come along with friends, family, and some like to look after the car themselves. It is a beautifully simple car, which responds to you as a driver, rather than needing setting up for a particular circuit.

'If you're racing a Formula Ford, for example, you need a Snetterton set-up and gear set, for example. Once you get an Academy car to work for you, it will work everywhere. That makes life simple.'

The Academy car weighs 625kg including driver, packs a 125bhp Sigma engine and uses a Mazda MX-5-derived, five-speed manual gearbox. It has an open differential and runs on low grip Toyo Proxes Comfort road tyres. This combination means the cars are fast and fun to drive, but also helps to hone the drivers' car control.

To keep set-up simple, for suspension there are standard fixed rate springs and dampers with no adjustability, and a choice between a ½in or ⅝in front anti-roll bar.

The cars at this level cost around £39,000 (approx. US$50,000), which also includes entry fees for the races.

Moving on up

Because the chassis is a spaceframe, the Academy cars are easy to fix in the event of a shunt, and this goes for the cars in the other championships too, as they all use the same basic design.

The second rung on the Caterham ladder is Roadsport, which offers a step up in spec from Academy, with Toyo R888R trackday tyres, a rear anti-roll bar and adjustable brake bias.

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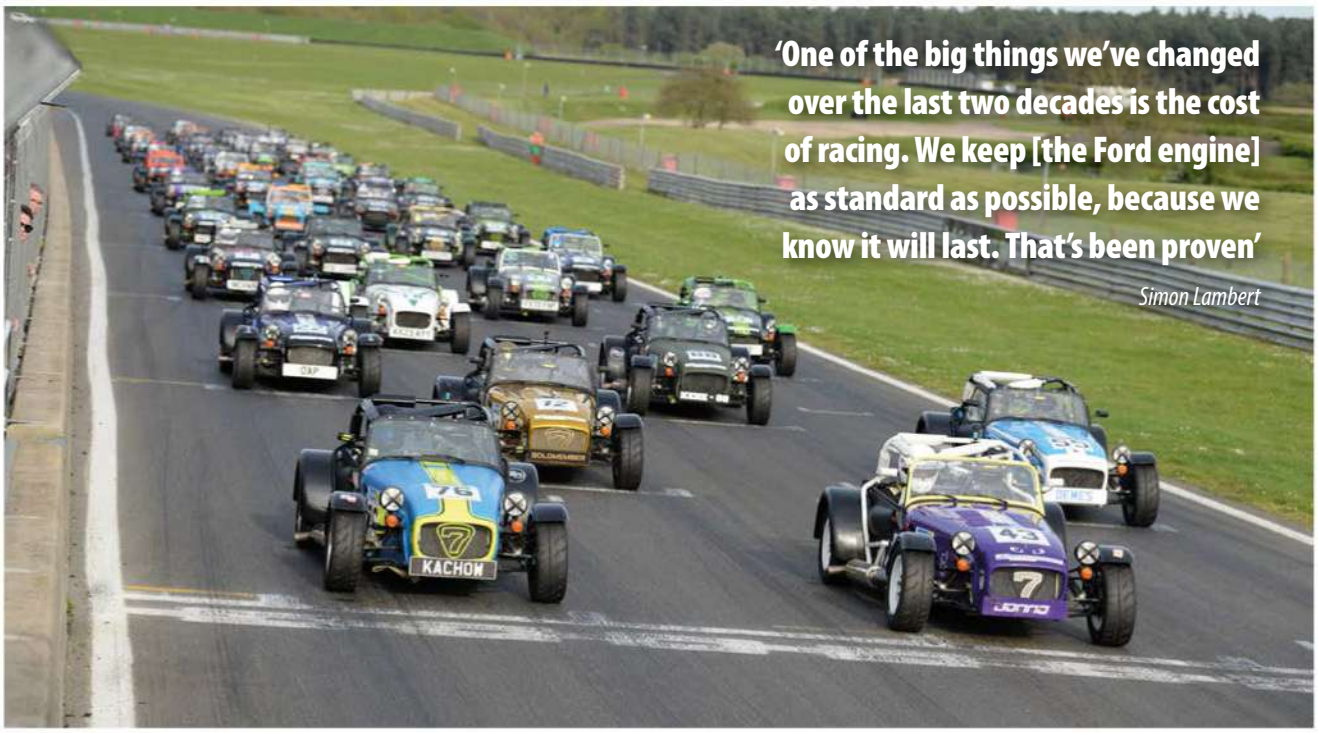
'One of the big things we've changed over the last two decades is the cost of racing. We keep [the Ford engine] as standard as possible, because we know it will last. That's been proven'
Simon Lambert
KACHOW

Packed grids are a feature of Caterham racing. Roadsport (shown) is a step up from entry-level Academy, with the cars featuring Toyo R888R trackday tyres and rear anti-roll bars

Next up from Roadsport is the Seven 270R championship, which is still fundamentally the same car as Academy and Roadsport, but sees the removal of the windscreen and lights, a wider track front suspension, stiffer springs and dampers and adjustable brake bias. This package is certainly more racecar than road car, and provides the first step on the ladder in which professional support, such as being run by a team, is allowed.

'What we want to achieve with each level is that you get out and say, that feels faster, straight away,' says Lambert. 'To feel the car is giving you something more.

'Going from Academy to Roadsport, you really feel the tyres and more rear control. Then you get to 270 and you've got the visceral feeling in the wind, and it's that much stiffer, it actually feels like a racecar. There is a slight rev increase too, because you take the windscreen off and there's less drag. That car feels markedly different and, typically, you get about a three per cent drop in lap times.'

The next step on the ladder is 310R, which brings with it a boost in power to 152bhp (the 310 refers to bhp per tonne) and a limited slip differential. The extra power is found with work on the cams and a re-flash tune, but it's still a 1600cc Sigma unit. Which, before we look at the top level Seven Championship UK, brings us to the elephant in the vroom, if you will excuse the pun. The Sigma engine is also no longer built by Ford.

'Its replacement will have to come along in a couple of years' time,' says Lambert confidently. 'It's going to happen. It's happened before, and we will deal with it. But it is a shame, as it's a great engine. It's served us really well and it's strong.

'One of the big things we've changed over the last two decades is the cost of racing. People were spending an awful lot of money on engine rebuilds, but the engine you get out of Ford has gone through multi-million-dollar tests to check how robust it is. We keep everything we can as standard as possible, because we know it will last. That's been proven.'

The engines have also proved equal in terms of performance. 'We seal them here, but we do that to the road engines, too,' continues Lambert. 'Because Ford have to build them to a tolerance, and this is the one area where really strict homologation rules have done us a favour: the engines you get are identical the whole way through. We used to dyno test engines, but after a while, when they're all identical, what's the point?'

Future engine

Caterham is now well advanced in its search for a new engine for these four championships, which presumably will be one of those it is currently assessing for the company's road cars.

Kevin Chapman, a former Minister Racing Engines employee who is now in charge of the engine shop at the new Caterham facility, is clear about the attributes it needs: 'It has to be short, narrow, powerful, reliable and it has to be able to be used as an inline engine.'

Most road-going Caterhams are now using the Duratec, and it's this engine that is used in the flagship Caterham class, for 420Rs and called the Seven Championship UK. In this case, though, some work is needed before it is put into the out and out racecar.

The 2.0-litre, 180bhp Duratec unit that's used in the top-level Seven UK championship for 420R racecars. These are fitted with bespoke pistons and camshafts to ensure all engines racing are exactly the same spec

'Because we can't buy the engine as it was when we originally started that championship, to make sure everyone has the same engine we have to buy all the parts to turn it back into the original engine,' explains Chapman. 'We change pistons and camshafts, which we have specially made now, so they're the same as those in the earlier engines.'

This 2.0-litre unit, unlike the others, is dry sumped and produces 180bhp, so is a step up on the Sigma's power levels. However, the 420R is also a little bit heavier than the other racecars, at 635kg including driver, due to the extra weight of the engine.

Lambert assures us the extra weight doesn't affect the car too much, and says, 'performance-wise, it's something like halfway up a GT4 grid.' Not bad at all for a car that costs around £54,000 (approx. $69,000).

Adding to the pure racecar feel, the 420R also features a Sadev six-speed sequential 'box.

'We have chosen not to go down the route of offering paddle shift with it, because that comes with its own problems,' notes Lambert. 'Plus, I feel like you're taking a bit of the driving [feel] away from it by doing that. We want people to heel and toe on the down changes, and you still have to do that with this manual gearbox.'

The springs and dampers are bespoke to the 420R, the latter having been developed by Bilstein, and there is no carbon on the car, to help keep costs down.

The Seven Championship UK cars run on Avon slicks and wets, and we're told Caterham has a large stock of these tyres, despite Avon Tyres folding recently (see *RE* V34N4 news), so it sees no need to change supplier for its flagship series for a while yet.

Winning formula

Each of the championships outlined here consistently attracts healthy grids, as do other series in which Caterhams are raced, and Lambert believes the reason for this popularity is the car itself and, ironically, some of its inherent design flaws.

'There are a few things we always have on our side,' says Lambert. 'It's a very simple car. It's a very low-cost car to run and to fix. It's incredibly durable, and it's so much fun to drive. However, if you were an engineer and were asked to design a new Caterham Seven, you would try and apply engineering theory and put all the mass in the middle, only to find it won't work. Our car is so much fun to drive because it's inherently flawed. The engine is too far forward, the driver too far back, so you have this really high polar moment, yet the car is communicating with you all the time.'

It's certainly been a winning formula, so it's no surprise to learn that – a new engine for the first four championships on the ladder in the next couple of years excepted – there are no plans to shake up the Caterham motorsport offering too much. There is, however, the chance that something entirely new may be on its way.

Slide rules

This, if it happens, will utilise the Caterham 170, the car which packs a turbocharged, 660cc, three-cylinder Suzuki Jimny engine and is all about light weight (440kg) rather than high power (84bhp), very much in keeping with the philosophy of Colin Chapman's original Lotus Seven. It also runs on skinny Toyo NanoEnergy 3 tyres.

'Our car is so much fun to drive because it's inherently flawed. The engine is too far forward, the driver too far back, so you have this really high polar moment, yet the car is communicating with you all the time'

Simon Lambert

The full-race 420R uses a Sadev six-speed, sequential gearbox with manual shift, but still retains much of the simple design philosophy of the other racecars, including outboard suspension

'We are currently exploring opportunities to race our lowest powered car, the Suzuki-engined car, on its 155 tyres,' says Lambert. 'That car on a circuit is just fantastic. It slides everywhere, but not big power slides because the fronts slide, too. It's like you're Stirling Moss, doing these big four-wheel drifts the whole way around the corner.

'The thought process is that it would be an entirely different type of race series. We're trying to recreate the '60s, almost. For that reason, we would probably do away with data logging, because it's not about tenths, it's just about driving enjoyment.

'So that is probably where the development is for us. If someone out there says that's the least likely track car there is, well, maybe so, but it's also the most fun.'

Which, in the final analysis, is what Caterhams are all about, on both road and track, and long may that continue.

The F1 effect

The Caterham name appeared briefly in Formula 1 from 2012 to 2014, but with little to show for its 56-race involvement beyond a brace of 11th place finishes. While the project bore the car firm's name, there was no involvement from the factory – they both operated independently under the Caterham Group umbrella – and it did cause its own peculiar problems for the motorsport department.

'It was entirely separate. It was owned by [Tony] Fernandes, and he just applied the name of Caterham to the existing Formula 1 team,' says Lambert. 'It gave us far more brand exposure but, from my world operating motorsport, it was a nightmare because people would charge us much more for testing, or whatever, and would say, "you can afford that now, you're an F1 team." It was a weird time.'

While there is no chance the Caterham name will re-enter Formula 1 in the foreseeable future, the F1 car Caterham now owns remains useful.

'It didn't do any good as a Formula 1 car,' says Laishley, 'but people still love it when they see it. We're going to have it in the factory, or at the Nürburgring, because one of our dealers has a new facility there.'

The short-lived Caterham Formula 1 team had very little to do with the road car maker, other than in name, and while its brief spell in grand prix racing brought worldwide exposure, it could not be considered a successful one

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Code red

The world of autonomous driving is about to take a step into the future using technology inspired by fighter aircraft and proven in motorsport

By ANDREW COTTON

Using expertise from the field of military aircraft, IRK is aiming to bring infrared technology into motorsport, along with other general applications

The digital world is on the cusp of taking a giant step forward thanks to a new infrared system that has been developed by British company, IR Kinetics (IRK). The firm, whose executive board includes a Formula 1 team founder, has re-purposed systems used on military aircraft and adapted it to be able to accurately track high speed vehicles, including cars, aircraft and trains, with a short-term view to generating new revenue streams for racing circuits, sponsors and suppliers, and a long-term view to drastically change the world in which we live.

There is nothing new or revolutionary about infrared technology, the principles of which have been known since the 19th century. The system merely uses sensors to provide highly accurate data of the location of objects. However, by repurposing the application of infrared, IRK hopes that it will be used in four key areas of our modern world: sports, gaming, transport and defence. Its potential, says the company, is huge, as it can free up capacity on the rail network, help to control autonomous cars, safely deliver supplies in war zones, and speed up decision making in sport such

An impressive team has been assembled including Professor Andrew Bradley (left), Gill Switalski (middle) and Lord Hesketh

as video assistant referee (VAR) procedures, or penalties for excessive track limit abuse.

Motorsport is playing a role in getting the concept up and running. Companies from the aforementioned four areas, plus the field of delivery systems, were invited by IRK to witness a demonstration at the Mallory Park circuit in Leicestershire late in August. Choosing motorsport to prove the system is not an accident. The environment is tightly controlled and regulated, creating an effective proving ground. Plus, the board of IRK includes Lord Alexander Hesketh, leader of the Hesketh Formula 1 team in the 1970s, who says that one of the key targets of the programme in terms of racing is to generate additional revenue to sporting arenas.

'The reason why it is in motor racing is that, fundamentally, you have to find an environment where you not only find a solution to technical problems, but also generate cash,' says Hesketh. 'No one can afford to pay for anything. [To be regulated, the system] needs to have a certificate, a licence and a regulator. In the UK, motor racing is probably better regulated than anywhere else, or at least is as well regulated. We have a system that generates money in new markets. The real key is to monetise a particular sport beyond the arena. If you can provide a digital picture, not an optical one - although you can turn the digital image back into an optical one - it can be streamed to every telephone at the Grand Prix at Silverstone. You can produce everything for the gaming market in real time, because it has to take place within 50ms.'

That digital map of the circuit is then available for use at any time of year, for any purpose, including computer gaming, vehicle development and driver training

The system may use existing technology and appear relatively simple, but a lot of technical research and development has taken place in the background. Up to eight years of work have gone into developing this system for its various applications; patents have been secured on various elements of it and now is the time to launch it onto the world stage.

High accuracy

Essentially, the system digitally maps the track to a high level of accuracy. This map is then available for further applications outside of the traditional race format, such as gaming. During the Mallory Park demonstration, infrared sensors were mounted to specially-made posts around the track. This was purely to ensure that the demonstration went well and could show the full range of options that are available and by no means is this level of detail necessary at each track. The sensors can just as easily be mounted to existing lamp posts or speaker posts.

Each car running on the track was then fitted with two LEDs that were mounted on the roof. These provided the accurate measurement of the car system that is needed by the infrared system, while other details such as the exact size and colour of the car could be stored digitally. By using infrared rather than video to monitor the location of a car, the package of data that is created and then transported back to race control is very small, measured in kilobytes rather than megabytes or gigabytes.

Race control can then use the data to automatically monitor the exact positioning of a car on the track, and automate decisions such as exceeding track limits or speeding under a safety car.

Aircraft link

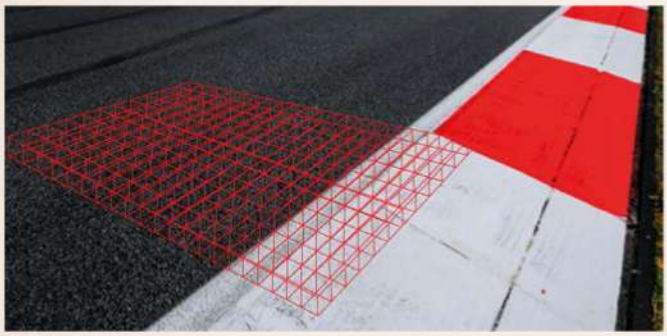
'The background is that I worked on the design of fighter aircraft, and they have infrared search and track sensors that complement radar,' says Professor Andrew Bradley, former systems engineering director at BAE Systems and chief engineer on the Hawk fighter aircraft. He is now the engineering specialist on the IRK project. 'They are forward-looking sensors, so the attack capabilities come from those sensors that detect targets. Radar is very good at telling you the range, but it is not that good at telling you the precise direction.

'The infrared tracker on the Typhoon [fighter jet] is a sensor that sits outside the cockpit. It is small, relatively cheap and passive, and doesn't emit radiation, so is covert in terms of defence. It detects thermal signature; any aircraft has a thermal hotspot, be it an engine or a missile. It can detect

The kit

IR Kinteics

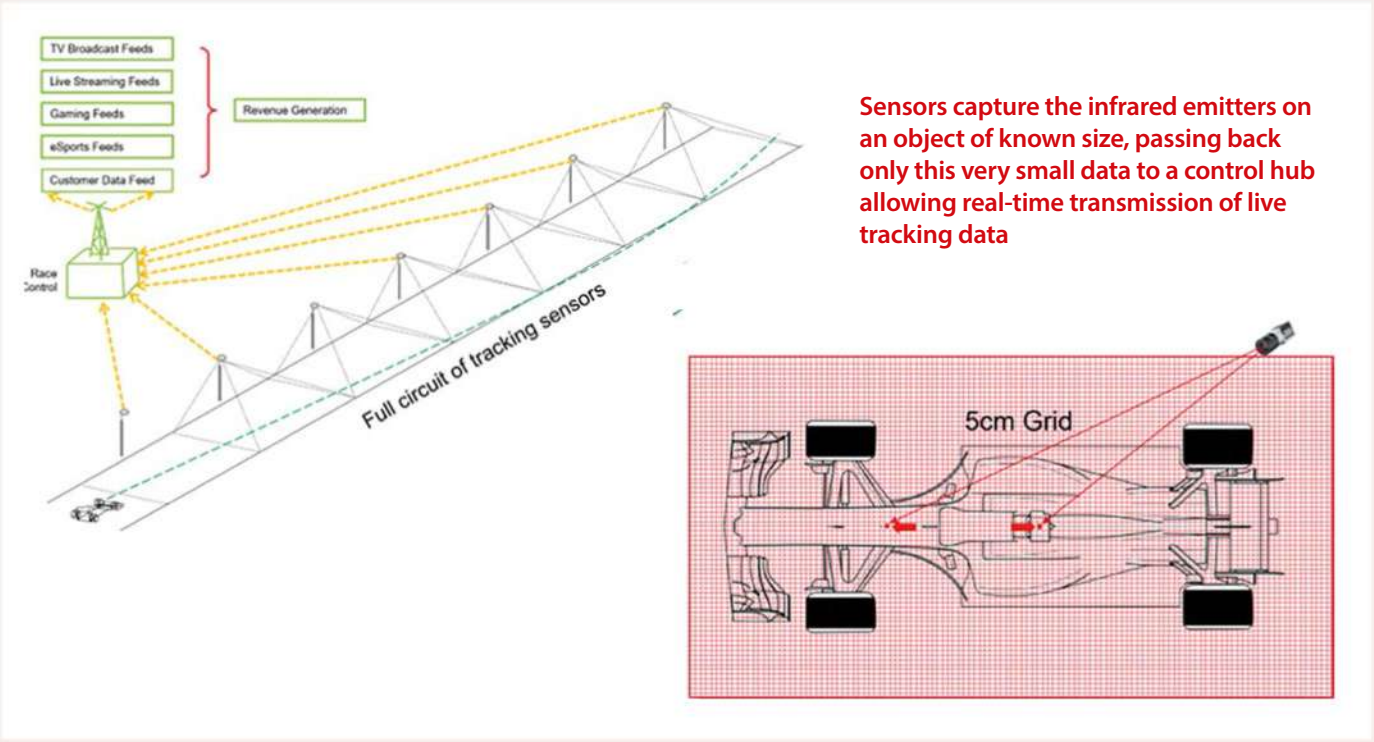
Scanners were originally taken from fighter aircraft, which are capable of tracking 100 supersonic targets such as fighter aircraft or missiles at a distance of 160 nautical miles, a little excessive for the needs of IRK



Accurate and highly detailed mapping of the Mallory Park track means that car location can be easily traced, and low volume data packages delivered safely to race control

The infrared sensors will pick up the trace of infrared emitters fitted to the car roof, which also help to identify the orientation of the car, its precise location and even in the case of motorways, what size of car it is. In racing terms, the possibility for sponsors to create their own online racing series exists, as does the chance to take part in races in real time

How it works



IR Kinteics

Sensors capture the infrared emitters on an object of known size, passing back only this very small data to a control hub allowing real-time transmission of live tracking data

Infrared light is invisible to the naked eye, but its presence can be observed by sensors. It has a longer wavelength than red visible light, but a shorter wavelength than microwaves

the direction, but not the range, so the two combine to give you everything you need.

'The original idea [of IRK] in 2016 was that racecars have hot tyres and engines so, if we use one of these sensors, hang it from a Goodyear Blimp or helicopter, we can track 24 vehicles easily because that's what it's designed to do: track multiple targets.'

The military-grade sensors originally considered were too expensive, so they were replaced with more commercially-available sensors, which is one of the ways IRK has brought down the cost of the system.

The full package is far more accurate than the GPS-based track limit detection system that was trialled by the GT World Challenge Europe series without much success. With the accuracy only to within around 3m and a slow refresh rate, the level of detail required to make a decision just wasn't there.

The IRK system also delivers only small data packages, has a refresh rate of 90Hz, compared to 1Hz for GPS, and allows for continuous tracking throughout a run. This accuracy and refresh speed is critical to the system, and means a car travelling at more than 200mph can be accurately tracked at all times. That would bode well if one were to consider the case of a passenger car travelling at around 70-80mph on a motorway, for example.

'Because we are using emitters on the vehicles, the cameras get lots of data, but the only data we are interested in is from the emitters, so that's a small package,

The IRK system delivers only small volume data packages, has a refresh rate of 90Hz, compared to 1Hz for GPS, and allows for continuous tracking throughout a run

and a small data stream, so it is practical to do it in real time,' says Bradley.

That data can then, as Hesketh has illustrated, be used to create other revenue streams. 'We know what we are doing and where we are going,' says Gillian Switalski, CEO of IRK. Switalski specialises in intellectual property law, and has gone to great lengths to secure the IP for this project. 'We can price for installation at a Grand Prix track of, say 5km, which would be about £3 million [US$3.9 million], but the prices will come down because we have created a prototype, the world's first digitised circuit, and we are bringing the prices down as we go along.

'We also have something like a menu, if you want all the bells and whistles, that's the price, and if you want it to do something else, that's another price. The most important thing in terms of motor racing is to create out of circuit revenue where it does not exist now, across any kind of motorsport, whether it is NASCAR, Formula 1 or Formula E. I describe the data that we generate as our black gold. If you look at smaller circuits, just lease it, and you can pay from the data that is generated, however you utilise that data.'

Using the data, a potential sponsor or supplier could develop its own race series or multiple series and deliver a highly accurate gaming experience to the global community.

Companies that have already expressed an interest in the technology, or have become partners, include McLaren, Toyota, Motorsport UK, NASCAR, Formula E and the FIA. This list alone shows the companies that see potential in such a system before it has launched.

One of the key partners, however, is global computer company Dell, which is providing the data support and security. Dell believes the system can be scaled up to other applications and that is where its true interest lies.

Away from racing, further interest has been garnered from the UK government, as well as defence companies, and the National Highways authority, which serves as a significant clue as to which direction IRK is heading.

Beyond racing

Once the system is created and developed, and proven in racing, the next stage is to scale it up for use in other applications, notably on the UK road network. The idea is to work with car manufacturers to use the autonomous functions that already exist in their vehicles, such as lane assist and variable distance control, to instruct a

car or lorry to remain in lane and at a safe distance from the vehicles around it.

'If you had sensors on every lamppost of the M62, or the M6 toll road, the fast lane would be repurposed as the autonomous lane,' explains Bradley. 'You would have LEDs on the car and could go autonomous. You already have the technology on the car, which goes as far as it can, but it is challenging to get a safety case for a motorway unless you have at least two independent tracking systems, one on the car and one like the equivalent of air traffic control.

'You couldn't get into an aircraft at a busy airport and take off and land without air traffic control, despite all the systems on the aeroplane. The two different systems combine to give the safety case. It is the same on railways. Roads, however, have never had this, which is why they are so unsafe. The autonomous guys say they want to be at least as safe as the current system, but we can do better.'

Traffic control

The idea of having an automated traffic control system has a financial benefit, too. Drivers of heavy goods vehicles, for example, who are restricted on the number of hours they can drive in any set period of time, would in theory be able to clock off on the long motorway sections of the journey, allowing the vehicle to continue while the driver takes a break rather than park in a layby, which would allow products to be delivered quicker than is currently the case.

'[Motorways] are linear, and are separated into different carriageways. If autonomous vehicles are anywhere, they will be there first'

Professor Andrew Bradley, engineering specialist at IRK

'[Motorways are an] uncluttered environment compared to country roads,' says Bradley. 'They are linear, and are separated into different carriageways. If autonomous vehicles are anywhere, they will be there first. While they only account for two per cent of the UK's strategic road network, they carry 30 per cent of the traffic.

'If you can get level four or five autonomy, then lorry drivers can go to sleep on these journeys and we can stop wasting time. [Drivers] can drive the city centres and country roads when they are awake, then go to a safety critical system that is safer than existing driving. That's the potential. There is no advantage to sitting there and waiting for something to happen, having to be alert and aware all the time.'

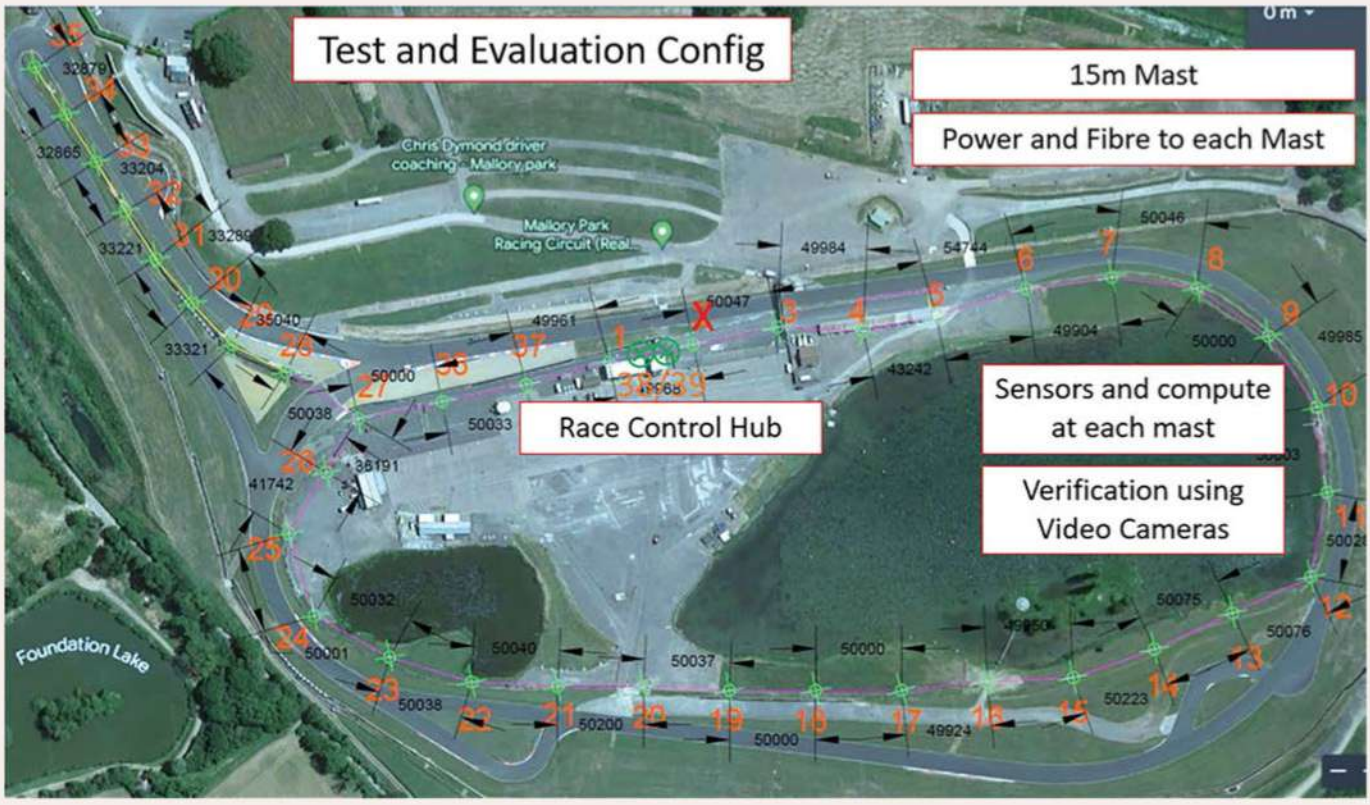
There is also the matter of electric cars, which do not refuel at regular stations but instead charge either at home, or at fast charging stations around the country, and do not contribute nearly the same tax revenue as ICE vehicles. Governments are already looking at ways to recoup the lost tax revenue, with road charging being one possible option. That also brings the IRK system into play. Using Automated Number Plate Recognition (ANPR), a vehicle can be identified entering an autonomous section of road, and monitored until it leaves, with a bill sent direct to the owner.

'Let's say you have the M6 toll road with an autonomous lane and you want to collect tolls,' says Bradley. 'With our system you wouldn't need booths. When you enter an autonomous motorway, the system detects what type of vehicle it is, and that relates to the LEDs on the vehicle, and where they are located. The sensors look down, so the LEDs have to be visible from above, so will be located in the roof.

'There would then be a standard data for the type of vehicle, so you'd know if it was a passenger car or a lorry, and the system can then track the footprint of that vehicle.

'Our patent says that, for example, a car can have two emitters, a light commercial vehicle three, in standard separations. They can be active or passive as well, as they can be switched on and off rapidly.'

IRK infrastructure programme delivery



Plan of the IRK system demonstration at Mallory Park. The route featured 39 posts mounted with sensors and computers; any posts can be used, meaning any track can run the technology

Autonomous Lane
UK Strategic Road Network
Linear & Decluttered. 2% of the total network, 30% of the traffic
Autonomous vehicles in this environment are achievable now...
IRK infrastructure complements on-board systems – enables robust Safety Case
IRK Infrastructure Architecture
Synchronous, Linear, Edge Network
Rolling Quadruplex Sensor Fusion
Independent, Diverse Safety Channel

IR Kinteics

IRK proposes that its infrared-based autonomous technology could transform road travel, enabling lorries to move while their driver rests and taking tax and toll payments on the go

Roads are not the only infrastructure project that IRK is hoping to target. The railway network in the UK is heavily congested, and while new infrastructure projects such as the High Speed 2 (HS2) railway have been curtailed, there is a pressing need to create more capacity.

On rails

Using the IRK system, the team believes that it can do just that. 'The actual lights cost nothing,' says Hesketh of the LEDs needed for the infrared cameras to pick up the vehicle. 'You can put lights on every piece of rolling stock, you can then track them on the electrified system, [which is used for most of the UK rail network]. What happens then is that you move beyond the Stephensons' [system] of block time signalling. The implications for that are huge, because you can vastly increase the capacity that a given line can take. It will mean the West and East coast [main] lines have more capacity for comparatively peanuts. What we really want to see is not [the recently-shelved high speed rail link] HS2, but something built in Crewe 15 years ago suddenly having a new life.'

Clearly having such accurate automation is going to have a military application, and IRK has already come up with a delivery system for supplies. The idea is to create a device, approximately the size of a hockey puck, that can provide accurate landing capability for a drone. This, then, would allow materials, such as munitions or plasma, to be delivered to a soldier in the battlefield.

A drone might follow a car around the track, providing safe data back to race control or the team, but that experience could then be applied to delivery companies, or military applications

'In a military application, in Ukraine there is a huge amount of radio interference going on and so you need a system that is RF [radio frequency] free, and you can do that,' says Hesketh. 'You put navigation with it and then you have an RF-free system, and then start to deliver medicine, for example. If you think about remote areas of the UK, without risking lives you can deliver significant payloads of a medical nature with no risk whatsoever. If you have tricky weather conditions, getting a lifeboat to someone in the water, it could deliver it straight to them.'

Further applications are also being considered. The scenario of a drone following a car around the track, providing data to race control or the team, could also be applied to delivery companies. They have traditionally been able to get their drones to a location, but accurate landings have presented a greater challenge. The puck idea would solve that issue, facilitating a safe landing on spaces such as a tower block balcony or small garden.

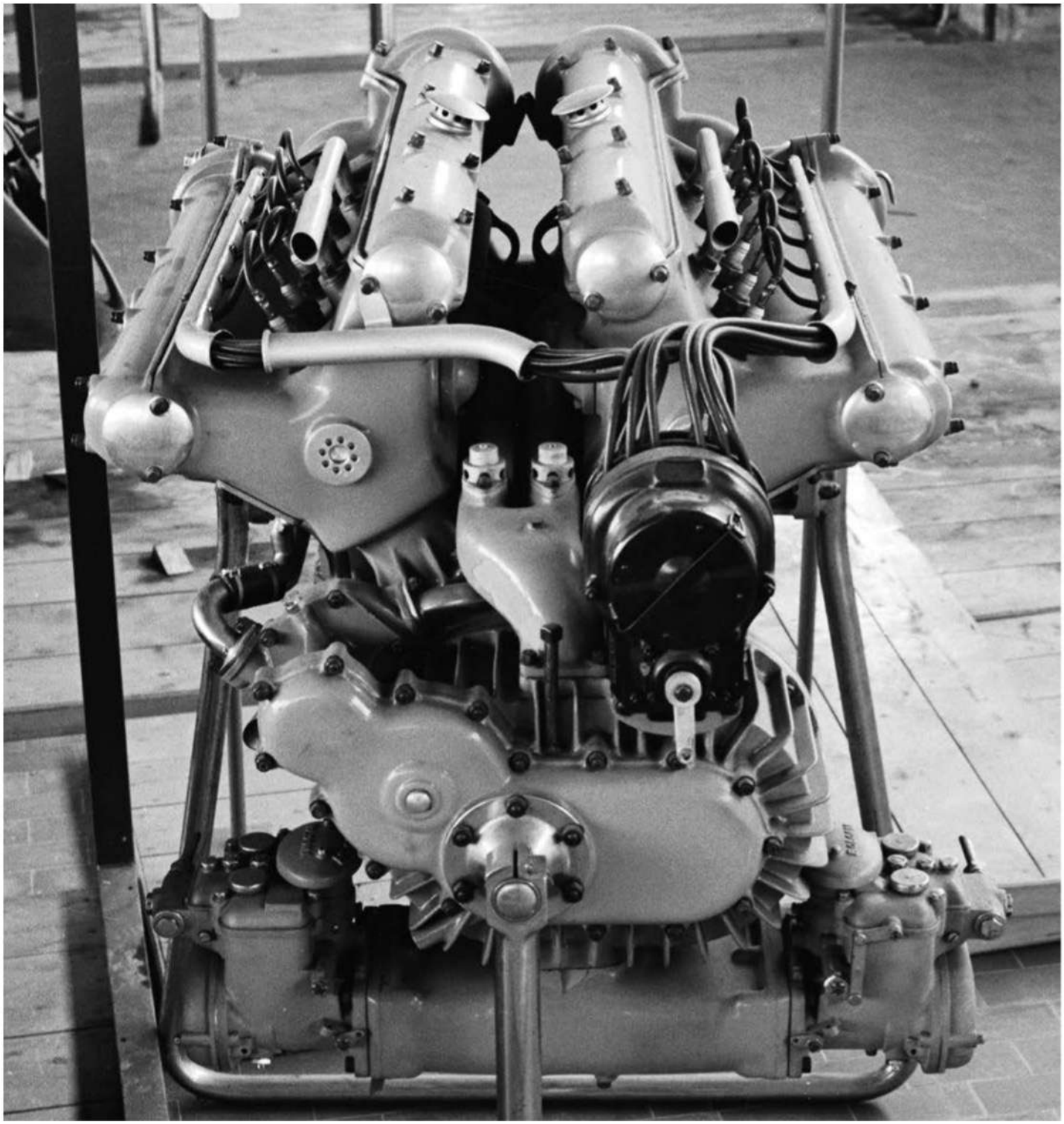
A code would then be given by the company which would then be able to dispatch the drone to the landing point, and deliver the item safely to the customer. There was at least one delivery company representative at Mallory Park in August.

Assuming adequate take up, the only remaining question is: how quickly could this scale up? The IRK board are clear; they can do so quickly as the components are not new, are widely available, and are relatively inexpensive. 'All of the component parts come off the shelf, so basically you have a standardised connectivity,' says Hesketh. 'The issue is the fundamental differences from sport to sport, use to use, industry to industry, but we are looking at being pretty certain of what we can deliver by November, and the question is who takes it, who wants it? I can't provide an answer to that.'

The power of 12

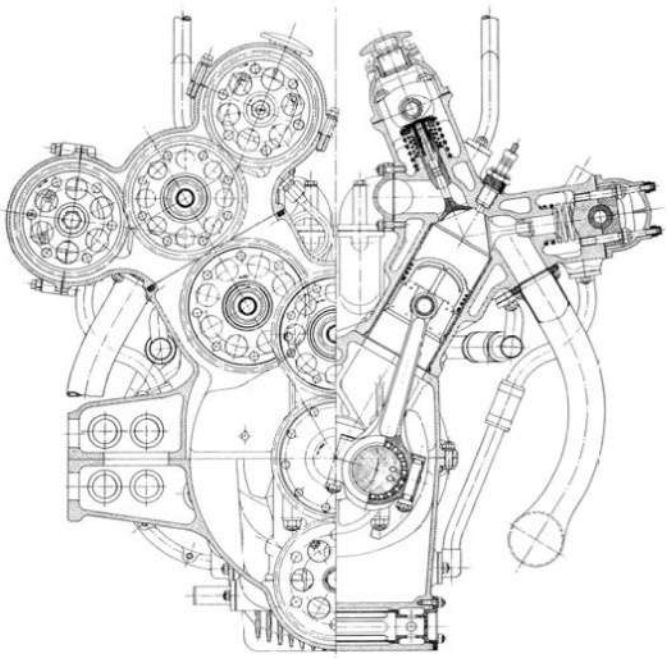
In the late 1930s, Alfa Romeo was instructed to build a V12 to propel its grand prix racers. Despite great adversity, the handsome car it powered became a fly in the ointment for the all-conquering German teams

By KARL LUDVIGSEN

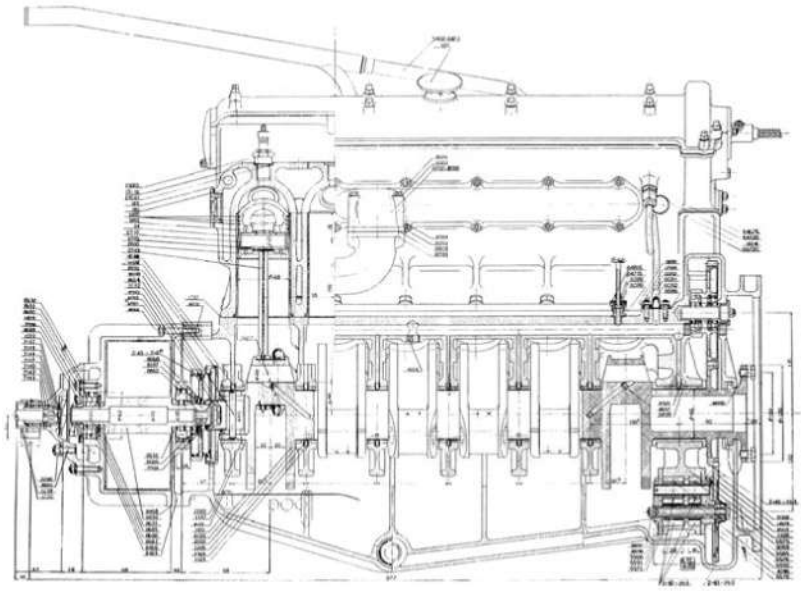


First raced in this configuration by the Italian manufacturer in 1936, Alfa Romeo's V12 then had a single Roots supercharger mounted low down at the front, fed by two carburettors from below

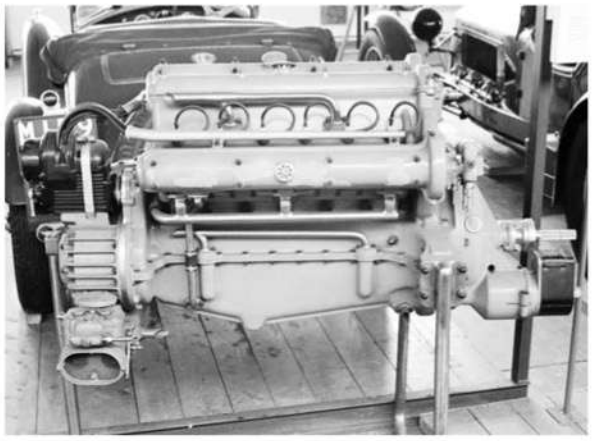
Wearing his trademark skullcap, star Italian driver Giuseppe Farina oversees preparation of the two Alfa Romeo 312s for practice before the 1938 German Grand Prix at the Nürburgring



Seen in its 3.0-litre configuration for 1938 / '39, the Trevisan-designed Alfa V12 now had roller bearing big ends. The gear train for its cam drive was at the rear



As configured for the Type 312, which arrived in time for the Tripoli Grand Prix in May 1936, the front gear train is now driving two Roots-style compressors, each serving one of the two banks of six cylinders



A left-side view of the V12 for sportscar duty (note starter motor) shows its cooling water distribution to the cylinders and finned Roots blower

When Alfa Romeo officially re-entered the grand prix wars in 1934, it quickly discovered its revised Type B was no match for the new cars Mercedes-Benz and Auto Union tailored to that year's new formula, which limited car weight to 750kg (1654lb), without tyres and liquids, and required a body width of 85cm (33.5in).

'This was intolerable to national pride,' said one observer of Alfa's eclipse, 'not only for sporting enthusiasts, but also for the national fascist hierarchy.'

Consequently, that same year Alfa's management commissioned celebrated Alfa engineer, Vittorio Jano, to commence work on a new grand prix car to uphold Italy's honour.

Jano's assignment was no sinecure. Since 1933, the boss of Alfa at Milan's Portello Works was former Fiat executive, Ugo Gobbato. Instead of desperately needed money and men, wrote colleague, Gioacchino Colombo, Gobbato motivated Jano with 'more or less authoritative messages, directives and appeals.'

In the factory, he said, there was 'great confusion about roles, too many people all wanting their own way in the matter of planning. It's a matter for amazement that he managed to build a vehicle at all under those conditions.'

On the plus side, the Gobbato regime relied on Alfa's high profile in motor racing to maintain the company's corporate standing. Mussolini was a keen racing enthusiast.

Independent thinking

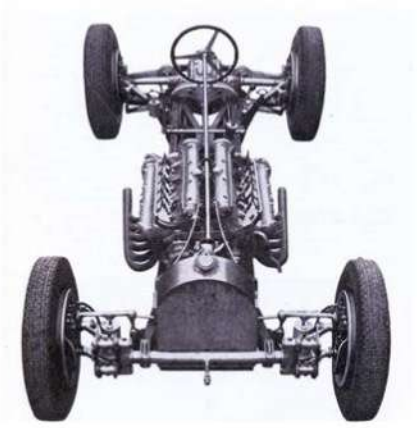
Like its road car counterparts, Jano's racecar had independent suspension. At the front, it used Porsche-type parallel trailing arms. Linked to the arms was a vertical tower that pressed the outboard end of a rocker arm whose chassis-mounted inboard pivot was rubber buffeted. Mid-way along the rocker was a link to a rod below that reached the bottom of a coil spring, inside a casing that was attached at its bottom to the chassis. When the road wheel jounced, the internal coil spring was compressed. For more sophisticated action, a second concentric coil could be added. Swing axles with a transverse leaf prevailed in the rear, carried by a frame of box-section tubes.

'It's a matter for amazement that [Vittorio Jano] managed to build a vehicle at all under those conditions'

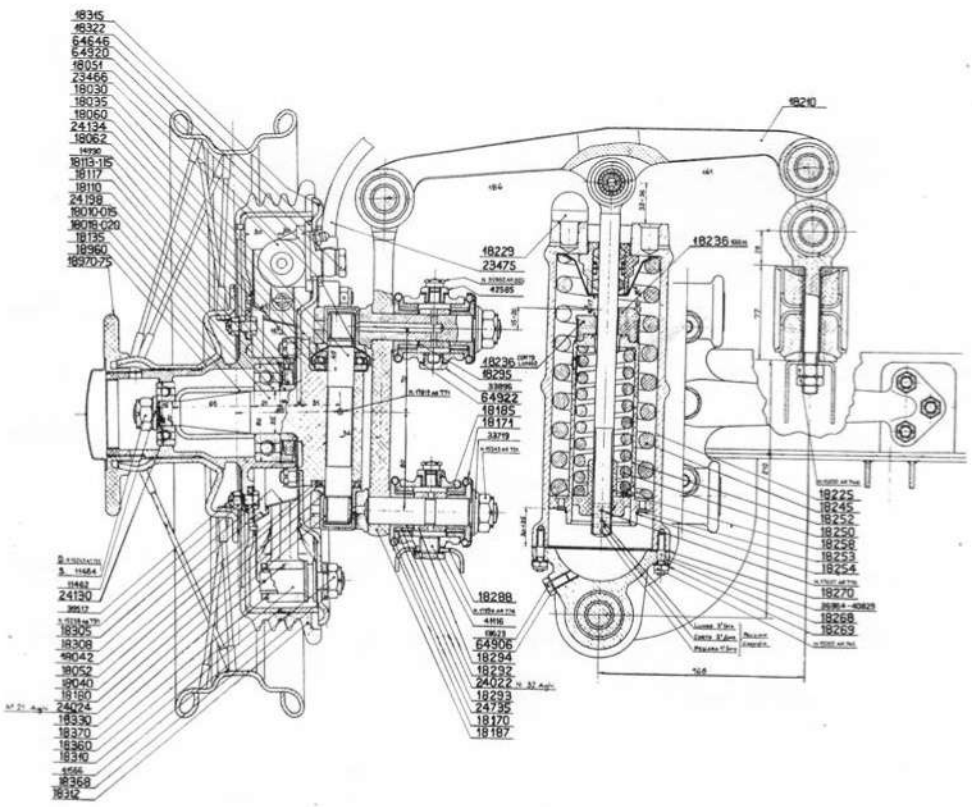
former Fiat executive, Gioacchino Colombo

The car's transmission was rear mounted, while its multi-disc clutch remained at the engine. Jano also planned a new 12-cylinder engine for the car but, when that wasn't ready, the new model was launched as the 8C, with an updated Type B engine, in September 1935.

If there was a fault in [Bruno] Trevisan's layout, it was its lack of full cooling around the valve guides in the heads, although this was not unusual in [Vittorio] Jano's designs



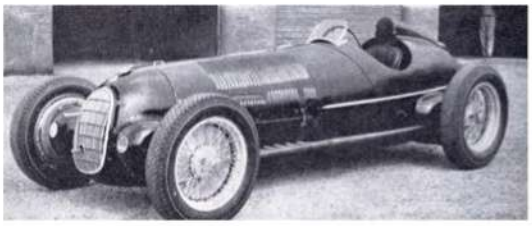
As rolled out for the 1937 season, the Type 12C-37 shows its very narrow central frame, a characteristic that did not serve it particularly well



Used in both road and racecars by Alfa Romeo, this was the detail of the elaborate front suspension. Note the near vertical kingpins

Alfa Romeo's low-line 12C-37 was its first effort to reduce the profile of its racecars for a reduced c of g and lower drag. The car is shown here at an early test

The narrow central frame passing under the machinery kept Alfa from making the best of its 12C-37, as this rear view suggests



The shape of the shroudings on the rear suspension was changed after the first appearance of the 12C-37. It impresses as a big machine

A few months later, on 10 May 1936, at the Tripoli Grand Prix, the car made its debut as originally planned, with its new V12 engine in place, as the Alfa Romeo 12C.

Trevisan 12

Jano entrusted a newcomer to Alfa with the task of detailing the new 12's design, under his direction. This was 43-year-old Bruno Trevisan, a reserve major in Italy's Air Force. Also an engine expert at Fiat, Trevisan moved to Milan in October 1934, just in time to start work on the new 12.

His engine was a work of commendable purity. Its vee angle was 60 degrees, with its right bank offset forward to allow side-by-side connecting rods. Two valves per cylinder were angled symmetrically at the wide spread that Jano favoured, 104 degrees, and equal in diameter at 35mm. With cylinder centre distances of 95mm, the 12's dimensions were 70 x 88mm, for a capacity of 4064cc (248ci).

All the engine's main castings were in light alloy, with the crankcase cast of magnesium alloy. Extending down to the crank centreline, where a magnesium sump added stiffness, the crankcase was literally that, with two aluminium cylinder blocks bolted to it. Each had integral heads and bores protected by thin, dry steel liners, held in place by a small flange at the base of the block.

If there was a fault in Trevisan's layout, it was its lack of full cooling around the valve guides in the heads, although this was not unusual in Jano's designs.

Each connecting rod journal was hollow bored to reduce its mass and opposed by double counterbalances. The forged-steel crankshaft was carried by seven 65mm main bearings oiled from a gallery running the length of the engine's central vee.

Slim-shanked, I-section connecting rods measured 190mm between their 22mm small ends and 60mm big end bearings. High-domed aluminium pistons, giving a 7.1:1 compression ratio, carried four rings and were well braced internally.

Above them, the valves were closed by triple coil springs, one large external spring and two shorter ones inside it. A thin mushroom tappet was screwed around the end of the valve stem and held laterally by the top of the valve guide, making for an exceptionally compact and light valve gear.

Four plain bearings supported each of the four overhead camshafts.

Trevisan divided the accessory loads between the front and rear of his 12-cylinder engine. At the output end, a gear train ran upward to the camshafts and downward to the two-section oil pump, integral with the massive rear main bearing cap, for the V12's dry sump oiling system. Driven directly from the nose of the crank was one 200mm lobe of a Roots supercharger that blew upward and back into inlet manifolds in the

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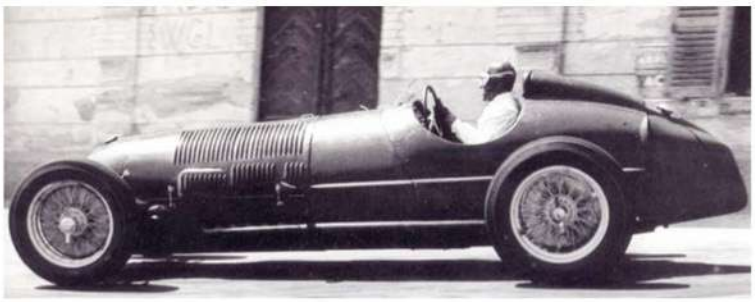
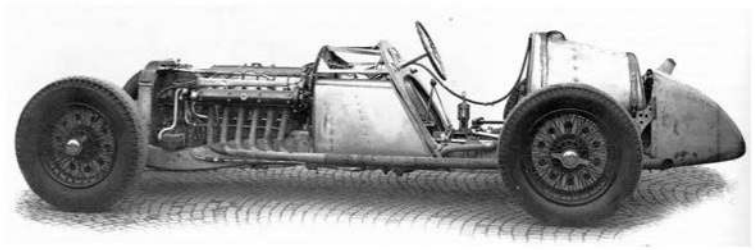
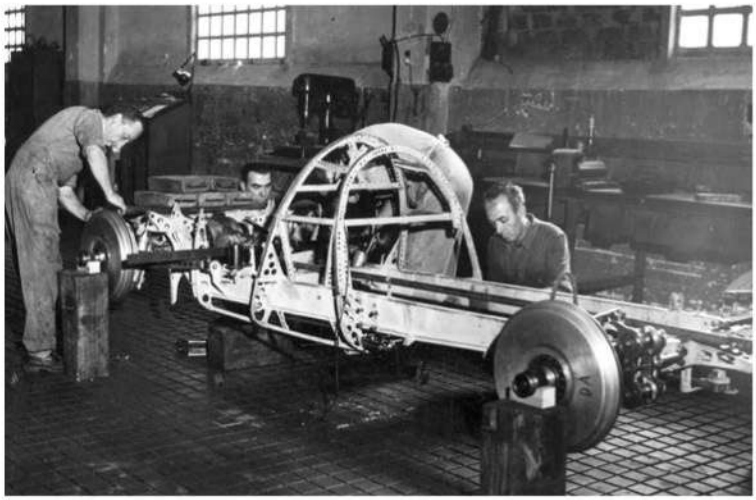
A test of the Type 12C-37 on the Bergamo Autostrada involved Tazio Nuvolari and, at the rear, Ugo Gobbato, who had much riding on the new car's performance



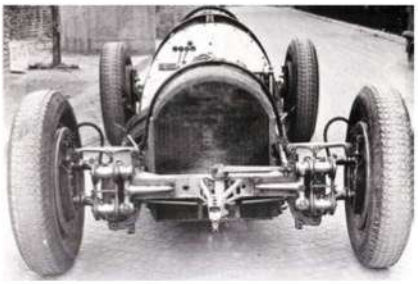
Nuvolari tried his considerable best to master the 12C-37 at Pescara's Coppa Ciano, but found it lacking, as did Farina who also drove it



The 3.0-litre V12 sat comfortably in the new car's chassis. The cowl's added fuel tanks are visible here, as is the dip in the V12's frame to accommodate its revised carburettors



Following rule changes in 1938, Alfa engineers prepared a new chassis for its Types 312 and 316, carrying their suspension designs over from the 12C-37. Arches at the cowl held twin fuel tanks



Below the 312's form-fitting water radiator was its oil cooler. At the rear, a swing axle and its radius rod can be seen

central vee that were partly integral with the blocks. Under it was the inlet ducting for two horizontally-mounted, twin-throat Weber carburettors.

Other gears turned the single magneto and the water pump on the right, from which two manifolds ran back along the blocks to inlets below the exhaust ports.

High hopes

By Alfa Romeo's standards this was an epic engine, its most potent yet. Boosted at 11psi, it produced 370bhp at 5800rpm.

'They were confident,' wrote journalist Laurence Pomeroy jnr, 'that with the extra power available from this they would be able to take full advantage of their new independently sprung chassis and re-assert in 1936 the supremacy which had been theirs only two seasons before.'

Enzo Ferrari's Scuderia Ferrari, which would enter the cars in races, also had high hopes for the new Type 12C-36. Six cars in all were made, plus four spare engines.

The first race outing at Tripoli on 10 May 1936 showed promise. On this very fast circuit, the Alfas were only two seconds slower than the Mercedes on a lap of 3¾ minutes. At the finish, however, the three 12s were sixth, seventh and eighth and, indeed, behind an older Alfa 8C in fifth, trailing the dominant German cars.

On a more challenging track at Barcelona's Montjuïc Park on 7 June, Tazio Nuvolari drove the sole 12C-36 to a tremendous victory over both German teams, despite two pit stops over 188 miles, due to the new car proving hard on its tyres.

Nuvolari would win three more times that year driving the new 12, at Milan, Modena and, most importantly, the 300-mile race on the new Roosevelt Raceway on New York's Long Island for the George Vanderbilt Cup.

More power

Impressive, yes, but those results were achieved in a poor Mercedes-Benz season. Jano knew he had to extract more power from his engine for 1937, the terminal season of the 750kg formula. Trevisan consequently enlarged both bore and stroke to 72 and 92mm respectively to push the capacity of the 12 up to 4495cc, while the compression ratio also rose, to 7.25:1. Boost pressure went up as well, to 12psi with higher supercharger efficiency, thanks to the use of two 105mm Roots blowers mounted side-by-side, running at 1½ times engine speed.

Jano knew he had to extract more power from his engine for 1937, the terminal season of the 750kg formula

High-speed durability benefited from caged roller bearings at the con rod big ends, on journals no longer bored for lightness.

Weighing 215kg (474lb), the revised engine produced 430bhp at 5800rpm. That was still overshadowed by the 575bhp on tap in the Mercedes-Benz, and Auto Union's 520+.

In the major races, the best Alfa Romeo could muster was Nuvolari's fourth in the German Grand Prix. In minor events, against occasional Auto Union entries, wins were achieved at Turin, Naples and Milan.

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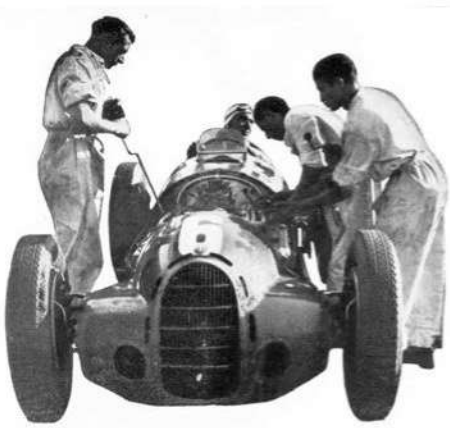
Much tidier at the rear than the 1937 12C-37, the 1938 312 is shown here preparing for a test at Monza, with Giuseppe Farina looking toward it



At an unidentified location, an Alfa 312 having its spark plugs changed. This model's front end had also received a number of alterations, seemingly aimed at improving cooling

That led Pomeroy jnr to write that 'during 1937, so far from narrowing the gap, Alfa Romeo fell farther behind.'

A further negative was that in March 1937, Alfa had bought 80 per cent of Scuderia Ferrari, but lacked the well-honed development capabilities of the Ferrari team.

Further evolution

Jano had nursed high expectations for his revised engine in a new, sleeker, low-chassis model with an unusual narrow frame intended to concentrate stress in the manner of a large central tube. Another new feature was the bulk of the fuel being carried in a cowl tank. However, with Jano's staff reduced to only a dozen people, only fitful progress was made in 1937, as Alfa engineer, Luigi Fusi, related: 'Unfortunately, owing to the pressing demand for aero engines, the manufacture of its various parts was delayed. The first tests on the new car were only carried out on the Bergamo Autostrada on 3 August. Following these tests, two cars were entered for the Coppa Acerbo at Pescara on 15 August.'

The new model was designated the Type 12C-37. Emphasising the manufacturer's substantial investment in Scuderia Ferrari, the Pescara race entry was made in the name of SA Alfa Romeo.

'The new, lower car was sleeker,' wrote historians, Leif Snellman and Hans Etzrodt, 'and had been tested at the Milano Autostrada by chief mechanic, Gianbattista Guidotti, and Tazio Nuvolari during the preceding days with satisfying results. Giuseppe Farina also tested the new car, supervised by designer, Vittorio Jano.'

The Pescara debacle

At Pescara, 'two of the new Alfa Romeos appeared on Saturday practice for Nuvolari and Farina,' added the historians. 'Nuvolari's best time trying hard for five laps was 11m26s [a minute longer than the best time]. The second car driven by Farina was not going at all well and broke down in practice.

A weathered image pictures the troubled Alfa racer at speed, its engine oil reservoir now sited in the tail

A driver of quality, Jean-Pierre Wimille, was a catch for Alfa. He competed in the August 1938 Coppa Ciano at Livorno, finishing fourth behind teammate, Farina

Frenchman, Wimille, also drove the 312 in the 1938 Swiss Grand Prix at Bremgarten, where he gridded on the third row aside Auto Union drivers, Nuvolari and Müller. He finished seventh, and last

'Nuvolari declared the new car not being ready to race but designer, Vittorio Jano, asked the Mantuan to test drive in the race, which would provide valuable data for the car's improvement.'

In the race, only Nuvolari started, but struggled to run in eighth position before handing the car to Farina, who retired the new Alfa before half distance.

'The debacle at Pescara was total,' wrote historian, Luca Dal Monte. 'At Portello, the situation was about to explode. Gobbato decided to wait and ponder.'

His eventual decision was for Scuderia Ferrari to prepare the known 12-cylinder cars for the Italian Grand Prix on 12 September and to enter a single Type 12C-37 for tester / racer, Guidotti, in the name of SA Alfa Romeo. The race would be on the twisty Livorno circuit, the characteristics of which – it was hoped – would annul the advantage of the rapid German teams.

Seen driving a T-car 312 during practice for the 1938 Swiss Grand Prix, Farina finished fifth behind three Mercedes and an Auto Union

In March 1937, Alfa had bought 80 per cent of Scuderia Ferrari, but lacked the well-honed development capabilities of the Ferrari team

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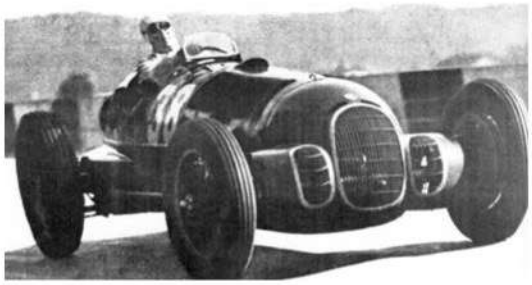
At Bremgarten in 1938, Wimille started ahead of Farina, but finished the wet race a lap in arrears of his teammate. Note the Alfa Romeo still relied on hand cranking to start the engine



In his usual imperious posture, Farina here is getting everything out of the 312. The addition of a small bonnet scoop helped cool the driver

In 1947, Alfa Romeo updated one of the existing Type 312 chassis, installing a 4.6-litre, supercharged V12 and giving it revised bodywork, more akin to its then successful Type 158

In its new surroundings, the Trevisan-created V12 engine looked quite at home. By this time, it had already become a legendary powerplant in the Alfa Romeo canon

The restored and re-bodied Type 312 kept the now outdated swing axle rear suspension but wore the latest Pirelli Stelvio racing tyres

In the event, Guidotti was lapped by the leaders after 10 of the race's 50 laps. Near the mid-point, he retired the car, which suffered slight damage when he left the track.

This catastrophic result, in front of a home crowd, and on familiar territory, noted Luigi Fusi, 'cost Jano his parting with Alfa Romeo.'

'The management was very hard, very severe,' recalled another engineer. 'However good you were, whatever brilliant work you had done in the past, if you did not deliver you could be dismissed.'

Sure enough, this was the fate of Jano, who was fired by Gobbato on 28 September.

It happened that the great pioneer, Vincenzo Lancia, had died the previous February, leaving a considerable technical vacuum in Turin. Jano therefore found a new home at Lancia, where he created a succession of fine road and racecars.

Alfa Corse

By the end of 1937, Alfa Romeo was ready to open its own racing department, Alfa Corse, in new, two-storey buildings at Portello. Gobbato was now the man from whom orders would flow to Trevisan, the newly appointed chief of racing.

From 1938, grand prix cars would be 4½-litres unblown, and 3.0-litres supercharged. Odds strongly favoured the latter, if higher fuel consumption could be tolerated. To take advantage of this, Alfa shrank both bore and stroke of its Trevisan-designed V12 to 66 and 73mm respectively, for a capacity of 2997cc (183ci).

Alfa Romeo's German rivals also built blown, 3.0-litre V12s to meet the new rules. Like Mercedes-Benz, the Italian outfit moved to two Roots-type blowers driven, like the magneto, by gearing from the nose of the crankshaft. Running at 1.5 times engine speed, the blowers, and their finned housings, were covered by a single casting neatly bolted to the front. To the left and right, large, twin-throat, horizontal carburettors prepared the mixture for delivery.

From 1938, grand prix cars would be 4½-litres unblown, and 3.0-litres supercharged. To take advantage of this, Alfa shrank both bore and stroke of its Trevisan-designed V12 to 66 and 73mm respectively, for a capacity of 2997cc (183ci)

While the Mercedes 12 claimed 8000rpm and the Auto Unions 7000, Alfa specified peak power at 6500rpm of 350bhp, well off the figures starting with four quoted by the Germans. The Italian cars' performance hinted that more revolutions were available.

Front and rear suspensions were carried over from the 12C-37 to a new chassis. The frame of Alfa's Type 312 for 1938 would allow a lower c of g, being based on a pair of hollow longerons with tall and narrow cross sections. The engine provided cross bracing, as did the arches carrying the cowl-mounted fuel tanks. Plural, as the Alfas split their fuel load between tanks flanking the cowl and another in the rear for better front / rear balance while fuel was consumed. Oil for the engine's dry-sump system was in a tank at the rear.

Weighing 880kg (1940lb) apiece, three of the new-for-1938 cars were built.

Dalliance and distraction

The 312's performance in its few 1938 appearances led many to suggest that this Alfa Romeo could be a contender, if its maker were inclined to back it with conviction. Problems in setting up the new Alfa Corse didn't help. Nor did Alfa's dalliance with eight and 16-cylinder engines for the new formula, and the distraction of its heightened interest in the 1½-litre Voiturette category, for which it created the eight-cylinder Type 158, designed by Gioacchino Colombo and built in Ferrari's Modena workshops.

All three 312s were at Tripoli in Libya, one of Italy's African protectorates, for the first big grand prix of '38 on 15 May. Four 312s were brought to Tripoli, but only three started, with the thrusting Farina showing the 312's potential by holding third place at quarter distance before crashing when squeezed by another driver. Another 12 crashed as well, killing Eugenio Siena.

Surviving was Frenchman, Raymond Sommer's, 312 in fourth position at the finish, eight minutes behind Rudolf Caracciola's third place Mercedes after 2½ hours of racing.

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Of two 312s in the 24 July German Grand Prix, starting from the fourth row, Clemente Biondetti's crashed and Farina's retired with radiator trouble.

Further duets competed at home on 7 August in the Coppa Ciano at Livorno and on 14 August in the Coppa Acerbo at Pescara. The first race was over 144 miles, the second 257 miles, and in both the Alfas had to give way to Mercedes-Benz.

At Livorno, Farina took third with Jean-Pierre Wimille, a welcome addition to the team, behind in fourth. At Pescara, two 312s faced six cars from both German teams. Biondetti's retired early with valve trouble but Farina placed second behind Caracciola, less than four minutes in arrears after three hours under a hot coastal sun.

For the 226-mile Swiss Grand Prix on 21 August, Wimille showed the pace available from the 312 by qualifying only two seconds behind most of the silver cars over a 160-second lap. On race day itself, though, in treacherous, rainy conditions, Farina finished fifth behind three Mercedes and an Auto Union, albeit two laps behind the winner after 50 laps. Wimille, meanwhile, was seventh in a sister car.

As installed in its post-war version, the Type 312 had the two Roots blowers visible side-by-side, sharing a single cover. Each was fed by its own carburettor

Achille Varzi, shown here at the wheel of the revised Type 312 placed at his disposal by Alfa Romeo after the Second World War, raced it with limited success in Formula Libre competitions in South America

Wimille and Piero Taruffi both had 312s for the all-important Italian GP at Monza, but both retired with engine maladies. Saving the day for Portello was a Type 316 (16 cylinders, as its name suggests), placing second behind Nuvolari in an Auto Union. This was the best finish achieved by Alfa's twin-crankshaft 3.0-litre, using the same chassis as the 312.

Final chapter

The next and final works entry of the Type 312 was made in the Belgian Grand Prix on 26 June 1939, where one was entrusted to Sommer. The reliable Frenchman finished fourth, twice lapped, behind the Germans in the wet race in which Britain's Mercedes star, Richard Seaman, was killed.

Thereafter, Alfa Romeo concentrated on the development and racing – into 1940 – of its Type 158, a 1.5-litre straight eight from Colombo that went on to become the leader of its class.

A handsome coda was Alfa Romeo's post-war creation of a racecar based on the Type 312 for South America's Formula Libre races. To be driven by Achille Varzi, it was re-bodied to resemble the 158s and given a 4.6-litre version of its supercharged V12. Though a magnificent looking car, the best Varzi could manage with it was a second at Mar del Plata.

The big Alfa was sold for 22 million lire to Clemar Bucci, who raced it in Argentina from 1949 to 1953. Re-bodied once again for sportscar racing, it was entered in the 1956 Buenos Aires 1000 kilometres for Bucci / Suarez, but didn't start. It was later converted back to a single seater by Tony Merrick and also by Symbolic. In August 2000, it returned to action at Laguna Seca and still turns heads in vintage car events today.

The Varzi car later became the property of Argentinean, Clemar Bucci, who competed with it often. Its livery at the time paid tribute to national icon Evita Perón

This survivor of Alfa Romeo's troubled 1930's racing era is now a prized exhibit at concours d'elegance events around the world. It is shown largely as raced, though now wears smaller rear wheels with larger section tyres than it raced on in period

Thankfully, this great Alfa racecar can still be seen at full power on track, driven by its present keeper. It's still started on the crank

Thereafter, Alfa Romeo concentrated on the development and racing – into 1940 – of its Type 158, a 1.5-litre straight eight from Gioacchino Colombo that went on to become the leader of its class

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Keeping active

With motor racing keeping a tight rein on moveable aero, it is left to the high-end road car manufacturers to continue developing the technology

By LAWRENCE BUTCHER

Active, or moveable, aerodynamic devices have long been a taboo in racing, banned by regulators and the subject of intense R&D by teams looking to maximise the grey areas of the rules. One only needs to look at the perennial furore surrounding bodywork flexibility in Formula 1 to understand their allure. Or the sly efforts that made it into the public domain. For example, in LMP1, Porsche's questionable rear bodywork on the 919 Hybrid in 2014 or, even more impressive, Toyota's shape shifting rear wing on the TS040 that same year.

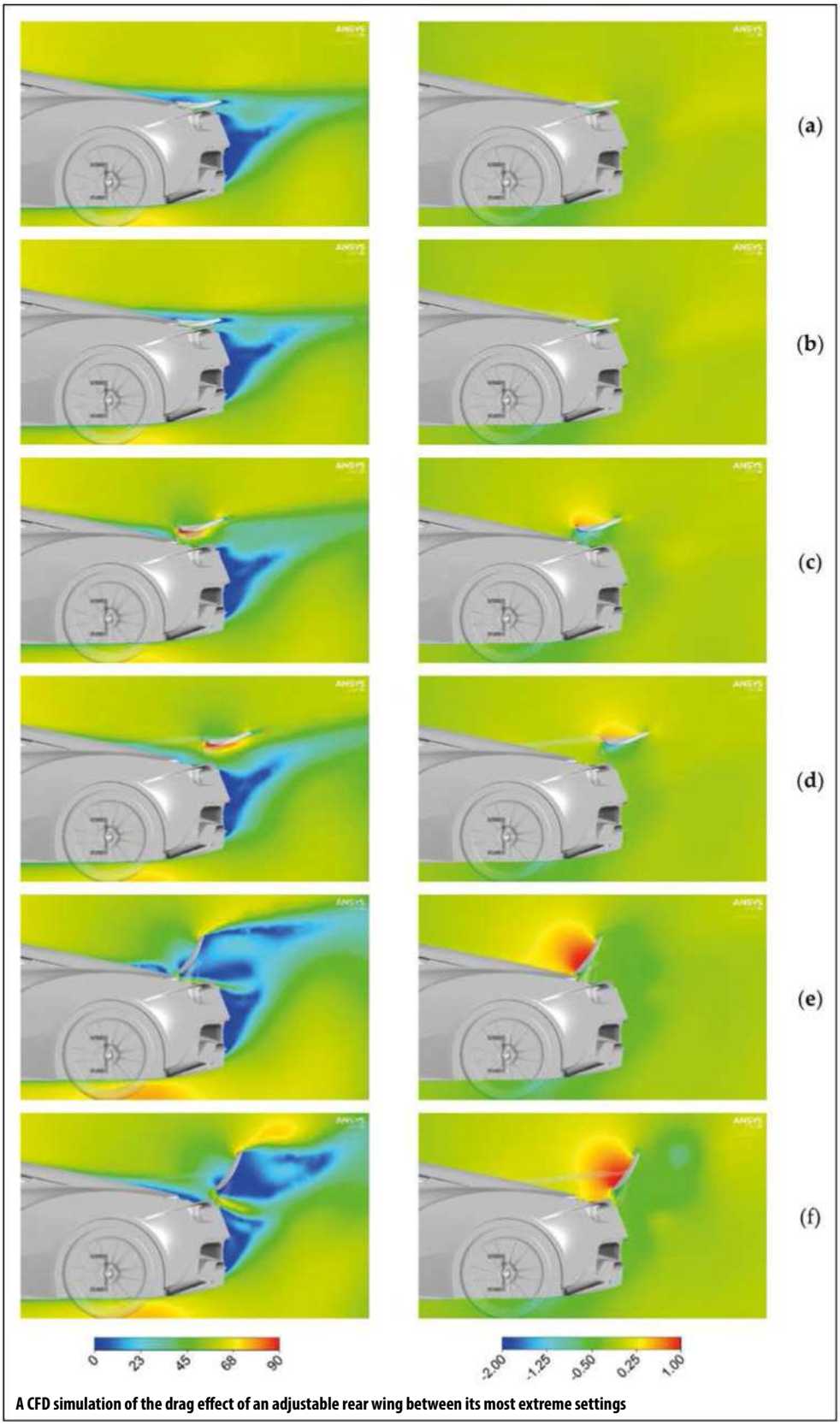
Of course, F1 has DRS (drag reduction system) but, relatively speaking – though the aerodynamic refinement and robustness of the actuation system is impressive – this is a very simple, driver-actuated device that is not too different from active systems raced decades ago.

Moveable aerodynamics are far from new and, until rule makers spoiled the teams' parties, plenty of them sought to harness the benefits. The first serious effort was in 1952. Mercedes briefly ran a large, roof-mounted air brake on its 300 SL during practice at Le Mans, operated by the driver using a foot pedal. Even back then, the organisers took exception and it never featured in a race. However, Mercedes stuck with the idea and, in 1955, the 300 SLR arrived sporting a rear-mounted air brake that sat flush with the bodywork when not deployed.

Air braking

According to *Motor Sport* magazine's Denis Jenkinson, reporting in period, drivers could even at times rely solely on the aerodynamic braking effect of the device, without need to resort to the mechanical brakes. The system apparently provided in the region of 0.31g of deceleration when deployed at 175mph.

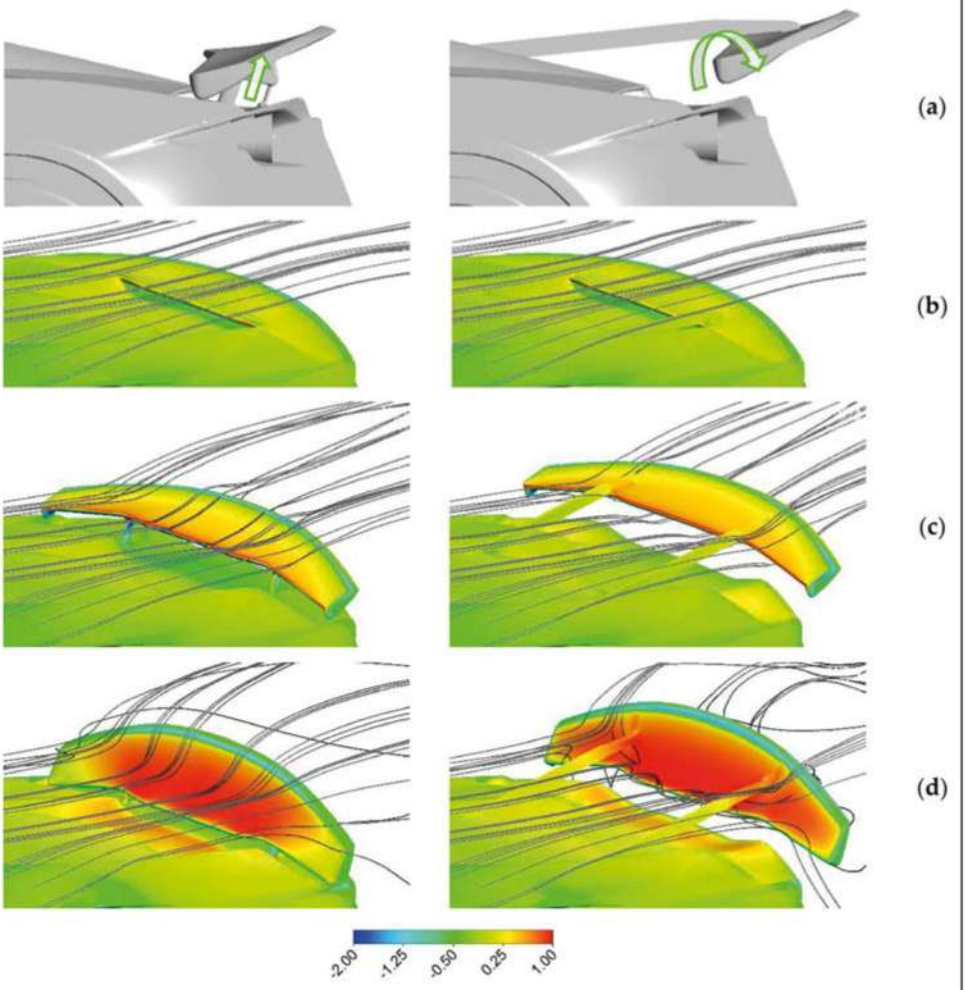
'Jenks' also noted that Stirling Moss mastered partly deploying the brake to help balance the car, commenting, 'an example was the bend after the pits, under the Dunlop Bridge. Without the air brake he had to lift the throttle and approach on the over-run and then open up round the bend. He found he could now take this bend without lifting his foot, losing the requisite speed by raising the air brake.'



A CFD simulation of the drag effect of an adjustable rear wing between its most extreme settings

Numerical study of the Sports Car Aerodynamic enhancements by Krzysztof Kurec

Numerical study of the Sports Car Aerodynamic enhancements by Krzysztof Kurec



CFD simulation showing the impact of differing mounting locations of airflow over an active rear wing

It's not hard to understand why. Partly raised, the brake was acting as a spoiler, reducing lift. In a parallel with modern approaches, the 300 SLR's brake was actuated using a hydraulic system, powered by a pump driven off the rear of the transmission, with control either via a driver-operated lever or an actuator integrated into the gearshift gate.

Mercedes withdrew from racing after the 1955 Le Mans disaster, but the following year, Swiss engineers, Pierre and Michael May, appeared with a Porsche 550 Spyder sporting an almost centrally-mounted aerofoil, the attitude of which could be altered from -3 to +17 degrees by the driver. The Mays' device was well ahead of its time, and even featured end plates that helped reduce drag. Apparently, it was capable of producing downforce equal to the weight of the car when fully deployed at over 90mph.

Unfortunately, the brothers made the mistake of upstaging the Porsche factory effort and, when they set out to race the cars at Monza, the Stuttgart marque's racing director, Huschke von Hanstein, objected strenuously to the scrutineers, claiming the wing hindered the visibility of (its) following drivers and could also be a danger to spectators. May was forced to remove the wing, and it never raced.

Extreme iterations

After that, it would be some time before moveable aero made a reappearance, but when it did people took notice. Always the visionary, Jim Hall's Chaparral 2C arrived in 1965 with a driver-actuated rear wing, implemented to help cure stability issues with previous versions of the car. From this stemmed various, increasingly extreme

The first serious effort was in 1952. Mercedes briefly ran a large, roof-mounted air brake on its 300 SL during practice at Le Mans

Danish supercar manufacturer, Zenvo, has developed a distinctive active aero system for its TSR-S road car. The rear wing tilts around corners, changing the lateral angle of attack by up to 20deg

As racing largely suppressed active aero innovation, road car engineers took up the mantle and have been responsible for most overt development since

The high-performance automotive sector is championing active aero, however such boundary-pushing projects often require the input of engineering companies with motorsport expertise

iterations, culminating in the 2J, replete with sliding side skirts and suction fan.

At that point, the FIA said enough was enough and tweaked the rules to clamp down on moveable aero, though Gordon Murray's Brabham BT46 sought to circumvent this in 1978 with its 'cooling' fan. Naturally, Colin Chapman tried his luck too, most notably with the 'twin' chassis Lotus 88 in 1981.

Later on, the DTM / International Touring Car Championship (ITC) Class 1 regulations of the mid-1990s, and associated Armageddon levels of spending from the manufacturers, brought forth a few notable highlights. For example, the Opel Calibra ran a system of moveable flaps on the front bumper that were able to close at high speed to reduce drag and then open on slower corners.

However, as racing largely suppressed active aero innovation, road car engineers took up the mantle and have been responsiblefor most overt development since.

Almost concurrent to motorsport widely outlawing moveable aero (with the exception of tricks such as McLaren's F-duct), road car manufacturers started to employ it. Most sources claim the Porsche 959 of 1986 was the first car to bring moveable aerodynamics to the road, but in fact it was a dead heat with the Lancia Thema 8.32, which featured a manually-activated rear spoiler. By 1988, the technology made it to the masses with the VW Corrado coupe's spoiler, which extended at speeds over 75mph. Fast forward to today, and such devices are de rigueur on many performance cars, but it is in the rarefied environs of supercars and hypercars where developments with the most interest to potential motorsport application have taken place.

Fully active rear wings, which can adjust their angle on the fly, are almost commonplace now. In the case of the Lamborghini Huracán, introduced in 2018,

Multimatic, a company with substantial motorsport heritage, has developed active aero systems including this three-position rear wing for the Ford GT and the moveable louvres for the Mercedes-AMG One, illustrated above

These louvres for the Mercedes-AMG One sit above the wheel arches, adding downforce and channelling air to intakes over the engine cover

engineers employed a split rear spoiler, with each flap individually adjustable. The idea was that greater downforce could be deployed to the inside, unloaded tyre when cornering.

The current crop of hypercars from the likes of Aston Martin and Gordon Murray Automotive take things to the next level, boasting a host of moveable flaps and spoilers, all controlled by complex algorithms feeding off data from various chassis sensors. With the production costs and construction techniques of [modern supercars] closely paralleling racing, many of the technologies being deployed on the road would be just as relevant to motorsport if permitted.

Actuation techniques

For the purposes of this article, we will ignore the aerodynamic design considerations of active systems, as these are often car specific, but all present similar challenges in terms of actuation.

In simple terms, there are three options available to operate aerodynamic elements: pneumatics, hydraulics or electronics. Predominantly, it is the latter two that are most commonly employed, each with their own pros and cons. As Jason

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Watkins, commercial director at Prodrive Advanced Technology, which has developed a range of active aerodynamic systems for manufacturers, outlines. 'Speed of deployment is great for a hydraulic system, because you can store pressure in a reservoir and have almost instant actuation, whereas with an electrical system, you need a huge surge of current for fast actuation,' he says.

It's worth noting, though, that the importance of deployment speed varies depending on the device.

'Something like a DRS, for example, you want that to deploy quickly because you want to create or remove drag quickly. If you deployed it more slowly, you can start to get a change in pitch of the vehicle in an undesirable way,' notes Watkins.

The capabilities of electrical actuators are improving, as are means of storing current to provide the power needed. However, even in vehicles using 48V electric architecture, particularly EVs where electrical power is not lacking, the sizing of cables and motors required to generate the necessary forces can be onerous.

That adds considerable appeal to the relative simplicity and power density of hydraulics, though, as you'd expect, there are trade-offs to be had. For example, with an IC engine spinning away, driving a hydraulic pump is not issue, but with an EV, a separate electrical pump is required.

'I was visiting a supercar manufacturer very recently, and it was interesting to see the dynamics going on between the innovations team and senior management about the direction of travel,' recalls Watkins. 'Do they go hydraulic [actuation], or do they go electrical? Because you get various trade-offs both ways. The senior management wanted electrical actuation, but the innovations team who were looking at the technology pointed out that everything just gets bigger and heavier, and then you're starting to compromise the package, compared to hydraulics.'

Bespoke solutions

Regardless of the approach taken, when it comes to moving large aerodynamic devices, there are very few off-the-shelf solutions available, which means the use of bespoke valves and pumps. The forces at play here are considerable, with Watkins noting that a recent project required a wing to be actuated into its full drag position at the equivalent of 350km/h with a 50km/h headwind.

Watkins also notes that hydraulic pressure vessels are available in other industries, such as aerospace, and Prodrive has deployed these in automotive applications.

'We try to look and see what is available on the market, rather than re-invent the wheel,' he says. 'In the automotive space, even at the high end, it is all very price conscious, so we're always playing that trade-off between what's available, what the customer is asking for and what they can afford.'

The moveable aerodynamic devices from Brabham's F1 1978 fan car are clear to see in the same designer's T.50 road car

The V12, twin-turbocharged Pagani Utopia is equipped with an active aero device on the rear that, according to the Italian manufacturer, combines with the electronically controlled suspension to produce 'maximum stability in every driving condition'

For less demanding applications, such as variable cooling vents and diverter flaps, electrical actuation is often more practical. A host of companies provide automotive-grade solenoids for such purposes and, where lower weight or greater robustness is required, high power density, 12V motors are available.

'In some cases, it can be just a simple solenoid actuation,' says Watkins. 'So you might have a ball screw operation or worm drive, but, typically, if you're just opening and closing something, that can be achieved with a fairly straightforward, robust solenoid system.'

Another benefit here is that there is no requirement for high-pressure plumbing to a vehicle's extremities, removing potential points of failure.

For less demanding applications, such as variable cooling vents and diverter flaps, electrical actuation is often more practical

Control strategy

Whichever way you look at it, controlling the deployment of active aerodynamics is a complex undertaking. Current motorsport systems, which are effectively only permitted in F1, along with some outliers such as Pikes Peak, are driver actuated and, while highly refined aerodynamically, don't even come close to realising the full potential of moveable aerodynamics.

In a true active system, movement of the devices, be that a rear wing or other element, will be initiated by the vehicle control unit, running a dedicated control model using inputs from sensors across the car. At a basic level, these will measure brake and throttle

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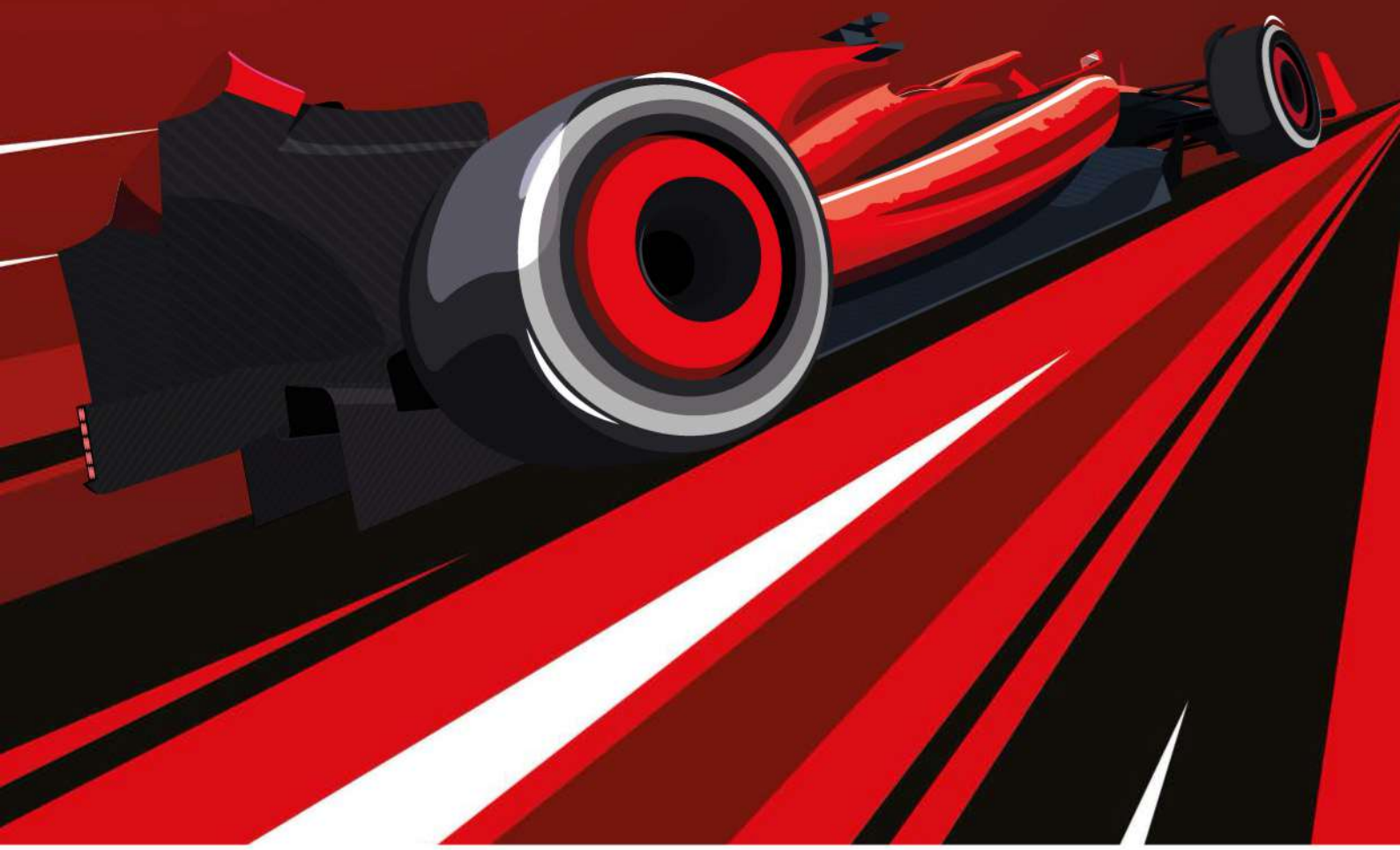

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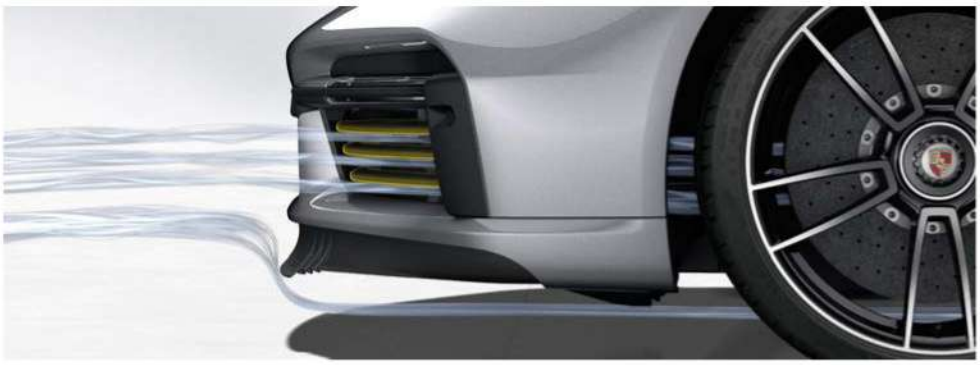
'As [active aero] is becoming commoditised, it is moving downstream. Even if you look at quite a regular EV, they have door handles that retract'

Jason Watkins, commercial director at Prodrive Advanced Technology



Porsche employs active cooling flaps and front splitter on the latest version of the 911, both controlled by electric servo motors

application, but the more complex set-ups currently used will also harness data such as steering angle, lateral g, wheel slip and more.

As the cars that Prodrive is currently involved with tend to be roadgoing, all of the control software is beholden to various functional safety rules and regulatory compliance requirements, which makes it considerably more complex than one would find in a racecar.

'Typically, that level of software is done at OEM level because they integrate it into the main vehicle electronics architecture. However, we do have our own electronic software and hardware, and software engineers, here on site writing chunks of code, though we tend to use that so we can test things as we're developing them, test what we're producing, test for production systems and so on,' says Watkins.

This code will be used for development validation testing and, even though production numbers tend to be very low, end-of-line testing before components are dispatched to the manufacturer.

'We obviously have to document exactly how our systems are designed to operate, what the design limits are, so those parameters can be incorporated into the OEM's software algorithms, while taking into account all of the other inputs from the vehicle,' adds Watkins.

Of course, in a racecar stetting, the sky is the limit in terms of the inputs and models that could be utilised to control an active aero package, were it to be allowed. With comprehensive aeromaps of cars available, and complete onboard data logging systems with inputs such as laser ride height sensors, it would be entirely feasible to map a system turn by turn at each track. It would even, theoretically, be possible to create a control model that considered tyre degradation over a stint and adjusted the aero balance automatically to account for this.

Motorsport future?

Sadly, from an engineering innovation perspective at least, the potential for fully active aero is unlikely to be fully realised in racing any time soon. Yes, F1 will adopt moveable front and rear devices in 2026, and there is talk of sportscars having some form of active aero in the future, but for now it remains the preserve of high-end road cars.

Watkins backs this up, saying Prodrive has seen little interest from mainstream racing, 'though we do see it from people who want to undertake a bespoke motorsport project, not necessarily competing at championship level with other competitors. We have a number of clients that are coming to us saying, "okay, we want to do a Nürburgring record car" and, obviously, active aero is a big part of that.'

However, he does suggest that if the move towards electrification continues, with efficiency ever more important, ignoring a topic that is so relevant to road car development would be a mistake. He also notes that the cost of even the most complex systems is coming down, again driven by demand from the road car market.

Hyundai's Active Air Skirt controls air turbulence around the wheels at high speed. Tests on an SUV saw drag coefficient reduce by 2.8 per cent

'We have two hydraulic-based programmes currently, and the cost difference between the two is a factor of 10. As [active aero] is becoming commoditised, it is moving downstream. Even if you look at quite a regular EV, they have door handles that retract – okay, that's a simplistic example, but what was once the preserve of cars like the McLaren P1 is becoming mainstream.'

Motorsport needs to keep itself relevant, more so these days than ever before. In an age when even companies such as Hyundai are deploying active aerodynamics to help reduce drag (search for its 'Active Air Skirt'), maybe it is time for regulators to reconsider their arguably blinkered stance?

Pikes Peak International Hill Climb has seen active aero innovations reach motorsport, including this design used on the Acura NSX Type S Active Aero Study car that entered the event last year

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The world of battery recycling is constantly changing.* Racecar *investigates the latest trends

By GEMMA HATTON

It is predicted that by 2035, 3.7 million tonnes of battery material will be available globally for recycling. This is because the typical life of a battery for an electric vehicle (EV) is around 10-15 years, so any EVs sold before 2020 will have batteries reaching the end of their life (EOL) by the mid-2030s.

So, what can we do with this surge of used batteries that are heading our way in 10 years' time? Well, batteries are made up of large quantities of valuable raw materials such as lithium, nickel, cobalt, copper and graphite. It is important to recover and re-use these materials as much as possible for a number of reasons.

Firstly, recycling batteries reduces the need to mine for virgin raw materials. This is an energy-consuming process, often driven by burning fossil fuels. Currently, up to ten per cent of the lithium and 18 per cent of the cobalt and nickel needed for manufacturing new batteries can be obtained from recycled old ones. Improving these figures would reduce carbon emissions and improve the overall life cycle analysis of batteries.

Furthermore, re-using batteries prevents hazardous materials entering the environment, and minimises dependency on importing raw materials, leading to a more secure and resilient supply chain. This is why battery recycling is becoming increasingly important, and why countries are pushing to achieve a circular battery economy.

A second life

From a life cycle analysis perspective, it is better to re-use or re-purpose batteries in secondary applications first, and then only after that look at recycling them for the raw materials contained within.

'There should be more emphasis on extracting the maximum value from the batteries first, rather than focusing on how to recycle them,' says Gerard Torres, chief commercial officer at motorsport battery manufacturer, Bold.

'A battery may have a life of 10 years for a particular application but, once it's degraded and not performing at the level required, it will still have some residual value. So the question then becomes how can we utilise that value in another application and extend its life by another 10 or 20 years?

'This not only helps improve a battery's life cycle emissions, but also gives us more time to refine the recycling process. Questions then include what technologies are most energy efficient? What materials will we get out of recycling and what materials do we need to put in?

'Understanding these points will help us develop recycling processes that retain as much value of the battery as possible, without having to spend significant CO_2.'

From a life cycle analysis perspective, it is better to re-use or re-purpose batteries in secondary applications first, and then only after that look at recycling them for the raw materials contained within

Managing waste

The first stage to managing waste batteries is to see if the cells can be re-used in a similar application. For example, a damaged EV may have some cells that still meet the

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Early recycling ethos was complete break down of batteries from the outset, but the view now is to explore second-life options first

Recyclus Group

Studies predict 3.7 million tonnes of battery material will be available for recycling by 2035, and the processes that make the component parts available for re-use are constantly being refined

Echion Technologies

With more batteries being produced around the world, the focus of manufacturers is changing, and recycling initiatives are shifting toward re-use and recovery programmes

performance requirements of an EV pack. This is the most effective way of retaining the cells' prior processing value.

However, once a battery's capacity has degraded so that it is no longer suitable for its original application, it can be re-purposed. This is where cells are switched to a less demanding role requiring lower power.

One of the most common second-life applications for lithium batteries is stationary energy storage systems, which are large sets of batteries, often topped up by local green energy sources such as solar, wind or hydrogen fuel cells. These power banks store and release energy when required, helping grid operators manage fluctuations in power or outages.

Only once all the capacity has been extracted from the cell should it move to recycling, where the components and raw materials can be recovered and anything left over eventually disposed of. So, which process suits which battery?

This is dictated primarily by the characteristics of the individual cells. Cells designed for high energy density usually have enough capacity left to be re-purposed, whereas cells with high power density typically go straight to recycling.

'Let's consider the batteries we supply for Extreme E, which are made from off-the-shelf cylindrical cells,' explains Doug Campling, motorsport director at Fortescue (formerly WAE). 'As these are high energy cells, even when their capacity is reduced so they are no longer suitable for motorsport, there is still plenty of capacity left for second-life applications. These cells can then be easily removed from packs and the modules used as building blocks to create stationary energy storage systems.'

Cells designed for high energy density usually have enough capacity left to be re-purposed, whereas cells with high power density typically go straight to recycling

In fact, some of the facilities involved in the running of an Extreme E event are already powered by stationary storage systems using re-purposed batteries from electric buses. Capable of storing 150kWh of energy and replenished by hydrogen fuel cells, Zenobē's Powerskids have helped Extreme E reduce 15 tonnes of CO_2 emissions each year.

'The crucial point about this approach to re-manufacturing is that you are using the module in its entirety as a common building block,' says Glen Pascoe, chief engineer of technology and innovation at Fortescue. 'This avoids the additional processing, and associated CO_2 footprint, of having to separate the individual cells,

The BMS monitors the battery's capacity throughout its life. As such, [it] is extremely sensitive IP for a manufacturer and so usually cannot be accessed, which has been a major barrier for battery recycling

removing welded busbars and ancillary components. You can evaluate a module consisting of many cells and re-use this quickly and efficiently.'

It's a different story, however, for the more exotic high power pouch cells used in LMDh, for example.

'These are low capacity cells, but with extremely high power,' explains Campling. 'This makes them less valuable for second-life applications, so this is where you enter a recycling process.'

Ways to recycle

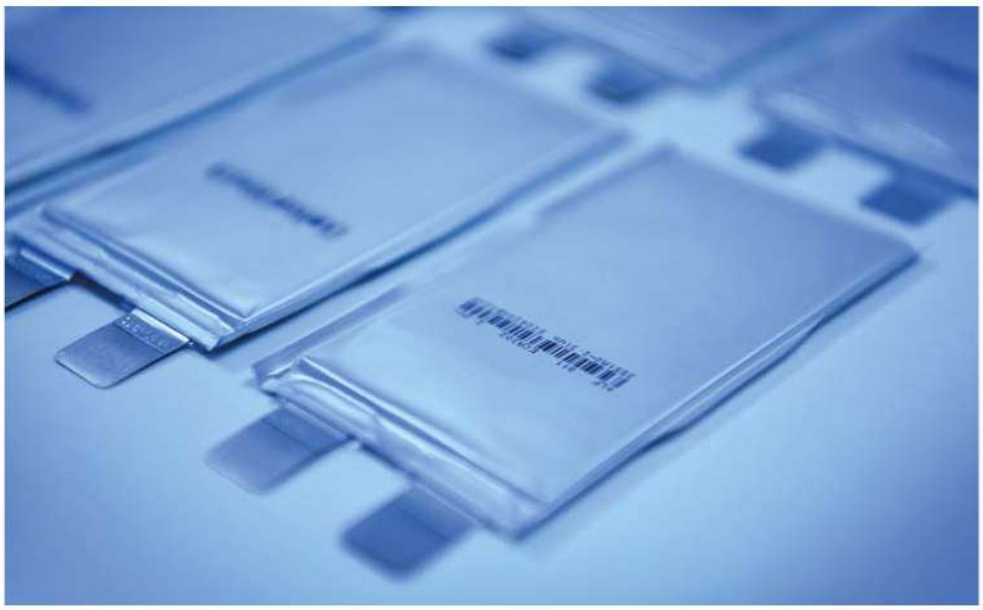
There are currently three main approaches to battery recycling: pyrometallurgy, hydrometallurgy and direct recycling.

Pyrometallurgy essentially uses extremely high temperatures to purify valuable metals. The first stage involves heating the cells to temperatures of between 140 and 500degC, which removes any electrolytes and organic solvents. Next, the cells are smelted at 1400-1700degC, which recovers alloys such as cobalt, copper and nickel, along with an oxide slag containing lithium and aluminium.

Although the recovered materials require further treatment to achieve the quality required to be re-used, pyrometallurgy is a simple and high capacity process that can cope with mixed waste streams. But by burning off materials, the lithium recovery rate is low and CO_2 is released, while a huge amount of energy is required for the process.

Hydrometallurgy, on the other hand, uses leaching agents, typically inorganic or organic acids, which dissolve the metals within batteries into a solution. These can then be separated and recovered with different agents used to extract particular metals. Consequently, less downstream processes are necessary to reach the quality of material required for re-manufacture when compared to pyrometallurgy.

Instead of dissolving or purifying the raw materials of the battery, the direct recycling approach aims to repair the cathode with minimal changes. This consumes much less energy and has few post-processing stages. However, the battery does require disassembly, which can be time consuming.



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Whether a battery can be re-used, re-purposed or recycled is determined by its energy and capacity characteristics, which in turn depend on the first-life usage. Pouch cells like these have low capacity but high power, making it harder to put them into second life

Recyclus Group

Less environmentally-friendly battery recycling processes see the cells shredded and then processed into 'black mass', which consists of base battery metals such as lithium, cobalt and nickel

Whether a battery is to be re-used, re-purposed or recycled, its state of health needs to be fully understood. This is determined by the battery management system (BMS), which monitors the battery's capacity throughout its life. As such, the BMS is extremely sensitive intellectual property for a manufacturer and so usually cannot be accessed, which has been a major barrier for battery recycling in the past.

State of health

'For re-purposing batteries, the great thing about motorsport, particularly when you support your products in the field, is we collect so much data,' says Pascoe. 'We know every time the vehicle goes out, how it has been driven and therefore the loads on the battery and the effect on its state of health.'

'As a metric, the state of health is informed using a number of factors, including SOC [state of charge] percentage, which provides us with the available voltage range and capacity,' adds Campling. 'This voltage and capacity information is then used by companies who re-purpose the batteries to characterise the modules and put modules of certain states of health together.

'In some cases, you can just hand over the batteries with their state of health information and the companies will characterise them accordingly and dispose of any they consider not to be viable. In other cases, they will set viability criteria, and you select the modules from your pool of batteries that meet that criteria.'

'Different applications accept batteries with varying states of health,' adds Pascoe.

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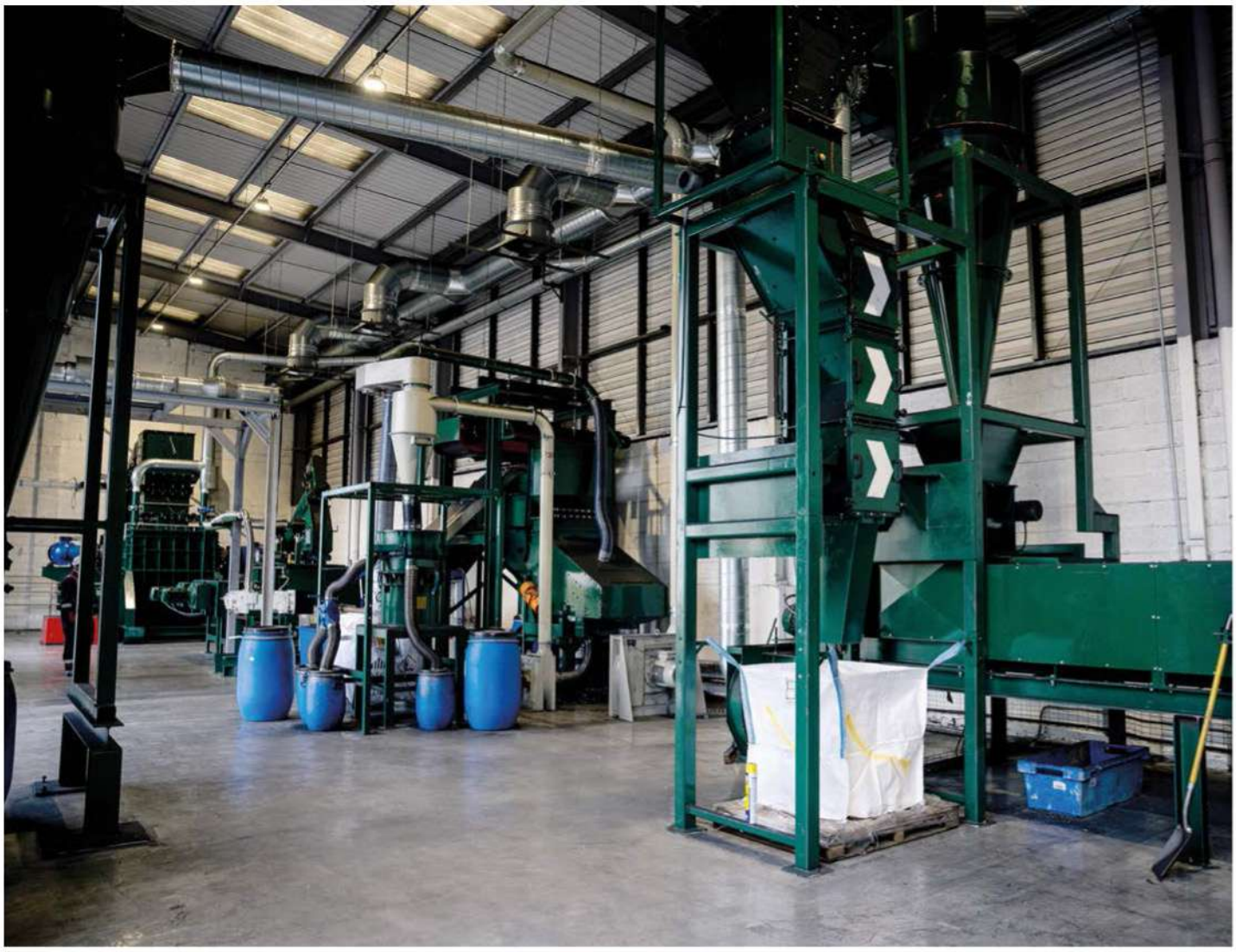

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Some recyclers will take batteries with any state of health, while others set viability criteria that need to be met. That could be state of power, ability to fast charge or previous faults

'So sometimes it's the state of charge that's important, whereas other times it's the state of power, the ability to fast charge or the back catalogue of faults and repairs needed to bring the battery into a useable condition.'

Battery assessment

When it comes to recycling a cell, there are two approaches taken. The majority of recyclers only accept cells that have been fully discharged, though there are others that have the procedures in place to safely handle, transport and process batteries that still carry charge.

'Before we give our batteries to third party recyclers, we run an assessment activity on the battery, mostly for safety purposes,' says Torres. 'We need to ensure that any component from the battery that goes outside of the company is safe to be handled and manipulated. This assessment typically involves disassembling the battery as much as possible and then fully discharging all of the cells so we are confident they are safe to be handled.'

Another difficulty when re-using and recycling battery packs is the number of components that need to be disassembled. A cell itself is relatively simple by design. It consists of four main parts and is approximately 40 per cent cathode, 25 per cent anode, 20 per cent current collector and 15 per cent electrolyte. However, when cells are grouped together to form a module, and several modules combined to form a pack, additional wiring, cooling and safety systems are required, plus a more complex casing. This can quickly escalate the number of components in a typical battery pack to over 1000 that require many different manufacturing methods to integrate.

'In motorsport, there is fortunately a pre-defined life cycle for components, either through the regulations of the series or a fixed-term contract of supply'

Glen Pascoe, chief engineer of technology and innovation at Fortescue

Disassembling all the components in a tightly packaged battery pack without damaging any of the constituent parts is a tricky task. Consequently, battery manufacturers now try to use as many common parts and manufacturing methods as possible within their designs.

'In motorsport, there is fortunately a pre-defined life cycle for components, either through the regulations of the series or a fixed-term contract of supply,' highlights Pascoe. 'Therefore, using simulation techniques, and through-life monitoring, you can accurately predict when your products are going to reach the end of their life, and it's important to design for that.

'We fundamentally design our batteries with re-use, re-manufacturing and recycling in mind. So, we specify as many common parts as possible, use common manufacturing methods to integrate those components into a pack and re-use our bespoke designed parts across multiple projects.'

'We apply the same methodology for our BMS, including the electronic boards,

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CMUs [cell monitoring units] and cooling fluids,' continues Pascoe. 'Also, because we support all our projects in the field, this enables even more re-manufacturing opportunities. We can replace large numbers of components on site without having to transport them back to the UK, saving emissions and costs.

'So, we really focus on designing for serviceability and this supports our end-of-life strategies. For cylindrical cells, that involves designing the module as a building block, and for pouch cells we focus on being able to easily remove cells for recycling and re-using as many components as possible in new module builds.'

In Extreme E (which will be supplanted by a hydrogen off-road championship next year) the cells can be used for two seasons, whereas Formula E and LMDh cells need to be replaced each season.

'It's all about how the cells are used and the cell technology that has been selected for each championship,' says Pascoe. 'In motorsport, we are able to push cells to their limits so, at the end of a first season for some series, you can't confidently get another full season of performance out of them.

'In this case, we recycle these cells, together with our partner, who uses a novel dry processing method that separates and recycles all the individual materials that make up a cell. In fact, at the end of the 2023 racing season, we recycled over 6.5 tonnes of lithium cells in the UK.'

Once Fortescue has replaced these cells with new ones, the company re-uses all the other components within the battery, which have been deliberately designed and tested to last for multiple racing seasons.

Cell refresh

'We essentially do a cell refresh between seasons for both Formula E and LMDh,' explains Campling. 'This means we replace the cells, but re-use the other parts. We use one set of parts for the modules for the first season battery packs, we then have a second set for season two packs, because these are built before the first season has finished.

'Then, when the season one packs come back to us, we dismount the cells and re-use as much as we can for the season three packs. We then continue to cycle these sets of parts, re-purposing them across the years we're contracted by a series to supply the batteries.'

'Economic viability will remain a challenge in battery recycling… true recycling ensures the valuable elements that make up cells are put back into the ecosystem to produce new cells'

Glen Pascoe

Despite the intense duty cycles motorsport batteries endure, the cells are no more difficult to recycle than other, more conventional chemistries. It has just taken time for recycling to become a priority as, previously, investment was focused on cell performance and extending life.

As battery technology has matured, customers and companies have shifted their attention to what happens to batteries in the after life. This has accelerated the development of recycling processes and helped establish best practices.

'Economic viability will remain a challenge in battery recycling,' says Pascoe. 'A lot of companies effectively down cycle the material, but true recycling ensures the valuable elements that make up cells are put back into the ecosystem to produce new cells. That takes a lot of processing which, inevitably, comes at a cost.

'Over the last 13 years we've been developing batteries, we've seen fundamental changes in the approach. We're no longer talking about just shredding an entire battery, or burning its contents, and we're focused on using refined, efficient and environmentally-friendly processes. Just like motorsport, the key is to strive for efficiency at each stage of the recycling process, which will improve overall economic viability.

'Ultimately, we haven't hit any major barriers when it comes to re-using, re-manufacturing or recycling. So, we're just getting on and doing it because it's the right thing to do.'

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Fortescue's Formula E batteries on display in the paddock at the London E-Prix. The cells within these packs need to be replaced at the end of each season as they are being pushed to their limits

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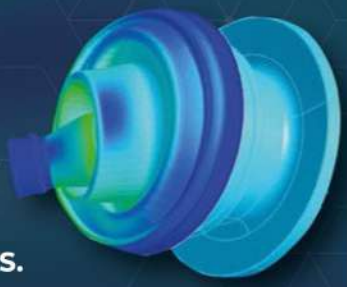

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Up the anti

Force-based anti-dive and anti-squat applied

By DANNY NOWLAN

Without doubt, one of the most hotly debated topics in motorsport engineering is suspension geometry. In particular, the subjects of anti-dive and anti-squat. And you had better be prepared for the ensuing fight if you dare mention that the conventional definitions of the two terms might actually be wrong!

Once you truly understand what drives anti-dive and anti-squat, however, you can use this to your advantage. That is what we'll be discussing in this article.

The first thing to get your head around is the force-based definition of anti-dive and anti-squat. As racecar engineers, we should all have a base level understanding of the lateral incarnation of this with roll centres. The kinematic and force-based version of this is about the same (albeit to quote Malcolm Oastler, former chief designer at Reynard and then BAR, the horizontal location of the roll centre has all the rigour of a middle-aged druid). However, for reasons that baffle my comprehension, that understanding never quite made the leap to anti-dive and anti-squat for so many people.

So, here goes. The force-based version of anti-dive and anti-squat is virtually identical to its force-based roll centre counterpart, as summarised in **figure 1**.

If you want to know what truly drives the longitudinal arrangement of your suspension arms, study **figure 1**, as it states it in a nutshell.

Proof of concept

Now, before you start saying ah, but this all falls apart because you have assumed the suspension elements are equidistant from the tyre centre and the top arm is parallel, that is only illustrated in that form here to make the proof easier. Should you be so inclined, you can study this in much greater detail in my book, *The Dynamics of The Race Car*.

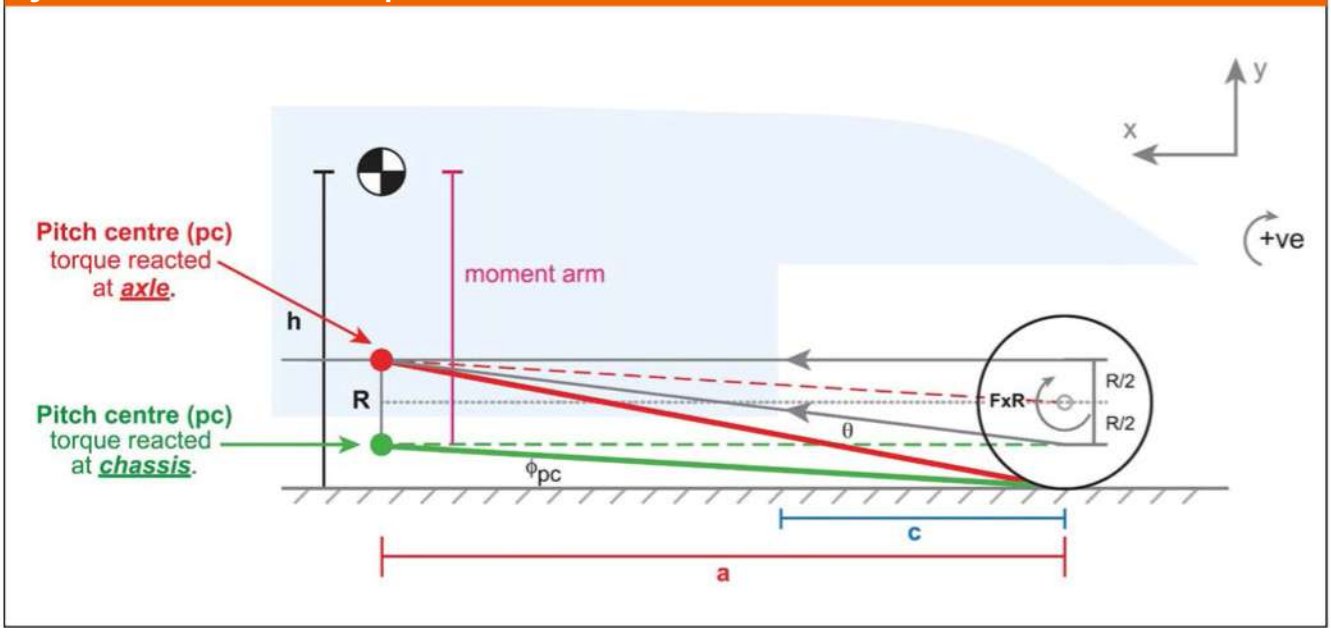
In short, where this all comes from is a free body diagram analysis of the hub, summing the applied forces and moments about the hub to zero. Then, to figure out how this is applied to the chassis, you take moments about the c of g.

The key thing to understand about force-based anti-dive and anti-squat is how the longitudinal torque is reacted. If the torque is reacted outboard, as you have when the brakes are mounted to the hub, or you are dealing with a live axle car, or an EV with a hub-mounted motor, then the force-based pitch centre is the red line in **figure 1**. That is to say, you find the instant centre of the suspension elements longitudinally, and you draw a line from the contact patch to this point. The pitch centre is the height from that line under the c of g, again as shown in **figure 1** (note I have shown the instant centre at the c of g line, just to make the illustration a bit clearer).

Where the torque is reacted at the chassis, such as in conventional differential arrangements under acceleration, or inboard-mounted brakes, you find out the instant centre, drop it by the tyre radius and that gives you a new line, the force-based pitch centre shown by the green line in **figure 1**. In this instance, the pitch centre drops by a tyre radius, in comparison to when the torque is applied at the hub.

The key thing to understand about force-based anti-dive and anti-squat is how the longitudinal torque is reacted

Fig 1: Force-based anti-dive and anti-squat



Once you understand that, and what it means, it makes analysing and designing suspension geometry so much more straightforward. The pitch centre is that point where the longitudinal forces are applied, and is the longitudinal analogue of the force-based roll centre, which is the pitch centre we just discussed.

Bring on the maths

Let's now look at how we mathematically represent this, because so often treatments of anti-dive / anti-squat are all over the place. The percentage of anti-dive / anti-squat is shown in **equation 1**.

$$ads\_fact_i = 100 * \frac{pc_i}{h_{cg}} \quad (1)$$

Where,

ads_fact_i = anti-dive / squat factor at wheel i
pc_i = pitch centre from the ground
h_{cg} = c of g height

Now, in terms of the jacking forces that are applied to the tyre and the chassis, **equation 2** is what you are looking at,

$$F_{z\_jack} = \frac{F_x \cdot pc}{a} \quad (2)$$

Where,

F_{z_jack} = jacking force
F_x = applied longitudinal force
pc = pitch centre from the ground
a = axle length from contact patch to c of g

Once you fully understand **equations 1** and **2**, and what they mean, it puts anti-dive and anti-squat on a more quantitative level. Let's now go one step further and take this concept for a spin but, before we do, let me just mention the most common error I see with anti-dive / anti-squat selection. This is illustrated in **figure 2**.

The reason I describe **figure 2** as poorly conditioned is twofold. Firstly, the instant centre lies well before the c of g. Typically, the anti-dive in this situation will land at 30-40 per cent. Then, when you add the tyre radius in, the anti-squat will drop below that – typically around 20 per cent.

If you have a situation like this on a racecar, you can expect some very Jekyll and Hyde-type behaviour as you get on and off the throttle. I'm not going to name names, but let's just say I've seen this on some spec formula racecars, the builders of which should really know better.

Figure 3 shows what a typical stability index plot in this situation looks like.

As can be seen in **figure 3**, just before the driver applies the brakes, the car has a low value of stability index, in the order of minus five per cent. When the throttle is applied, this drops down by at least 10 per cent, and the culprit for that is what is shown in **figure 2**. And you wonder why everyone looks shocked, and why the drivers aren't learning anything…

About the only time I would even consider something like this is when you

Fig 2: Poorly conditioned anti-dive and anti-squat

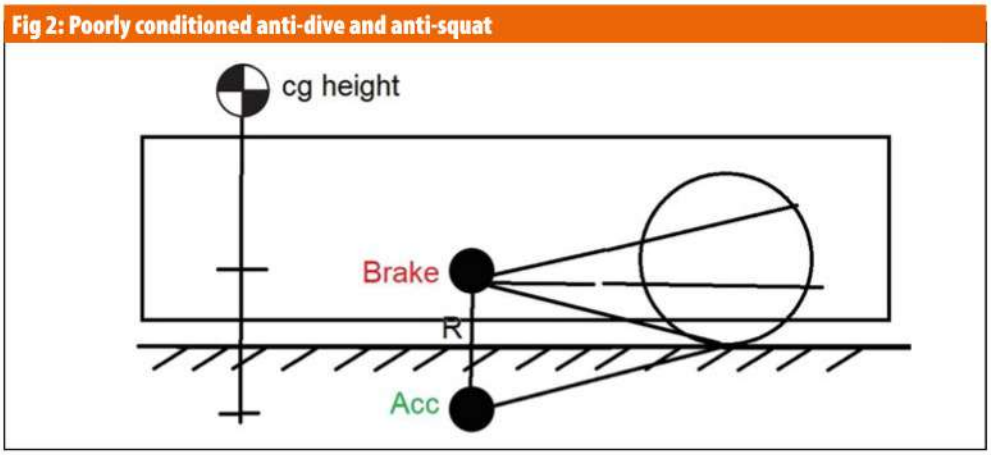
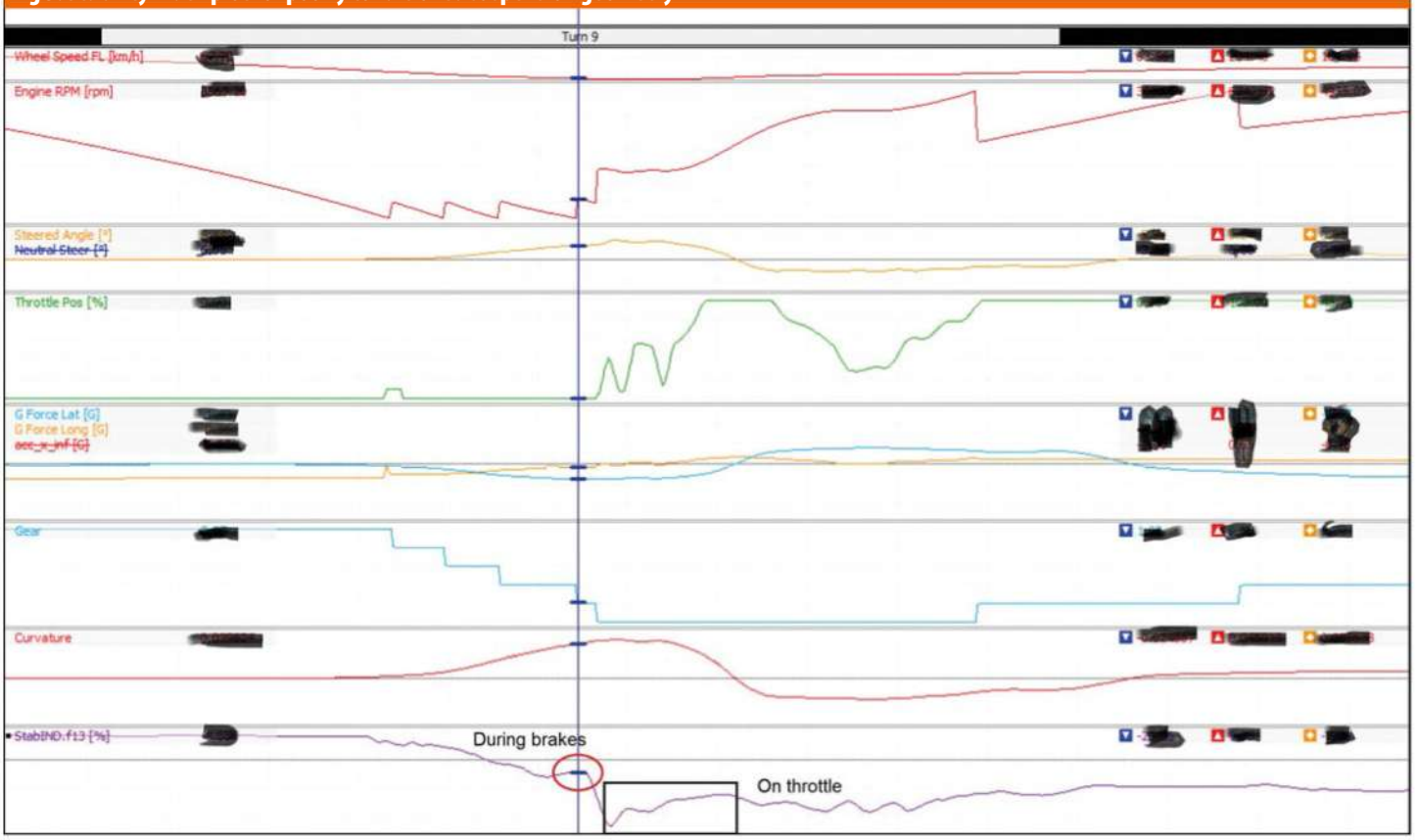


Fig 3: Stability index plot for poorly conditioned suspension geometry



The further in front the instant centre goes, the less variation you can get, and that will yield a car that is much more consistent

have a car that is pitch sensitive, and you need that sensitivity to rotate you into the corner before you have to stabilise the car at the mid-corner point.

It will work, but there are also times where you will be caught with your trousers down and have to resort to drastic measures.

What you should be aiming for is the longitudinal instant centre well past the c of g point, as illustrated in **figure 4**.

I'll happily admit **figure 4** is a bit crude, but it illustrates what happens when the instant centre finds itself well projected in front of the c of g. Those wild variations that we saw in **figures 2** and **3** simply cannot happen now. Also, the further in front the instant centre goes, the less variation you can get, and that will yield a car that is much more consistent.

So, what tools are out there to help us quantify all this? A couple of years ago I was working on a Hypercar project and added a tool into ChassisSim for this very purpose.

That shown in **figure 5** will not win any awards for being pretty, but it is extremely useful. You simply plug in your points and click on 'Analyse configuration'. Then, when you click on the box shown in step 2, it will show you exactly where the instant centre length is and the swing arm length. You can then manipulate this to see what you need.

Conclusion

In closing, force-based anti-dive and anti-squat is not just a very powerful way of visualising suspension geometry. It allows you, as an engineer, to quantify what is going on with your geometry correctly. It also starts to answer a lot of those questions that were in your head, but maybe you were too afraid to ask.

The real take away from this, though, is to manage your instant centre location and swing arm lengths to achieve the goal of what you want to do. Get that straight in your head and it will serve you well in your career as a racecar engineer.

Fig 4: Well conditioned anti-dive and anti-squat

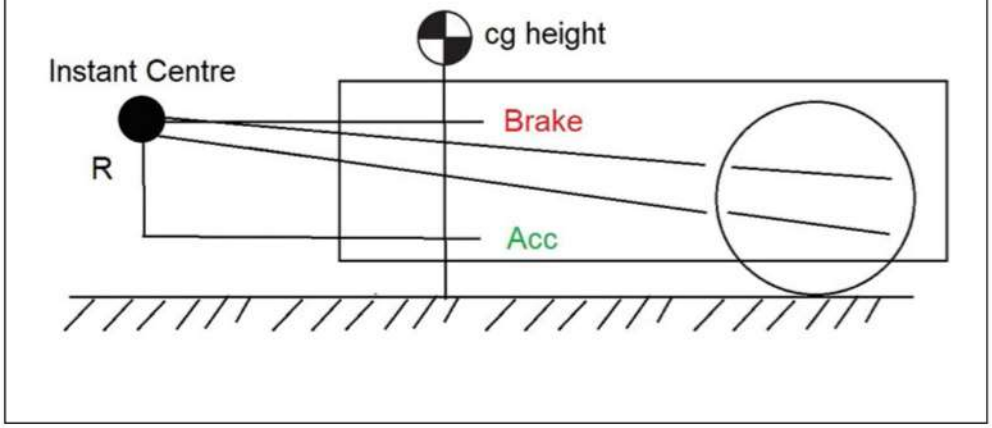
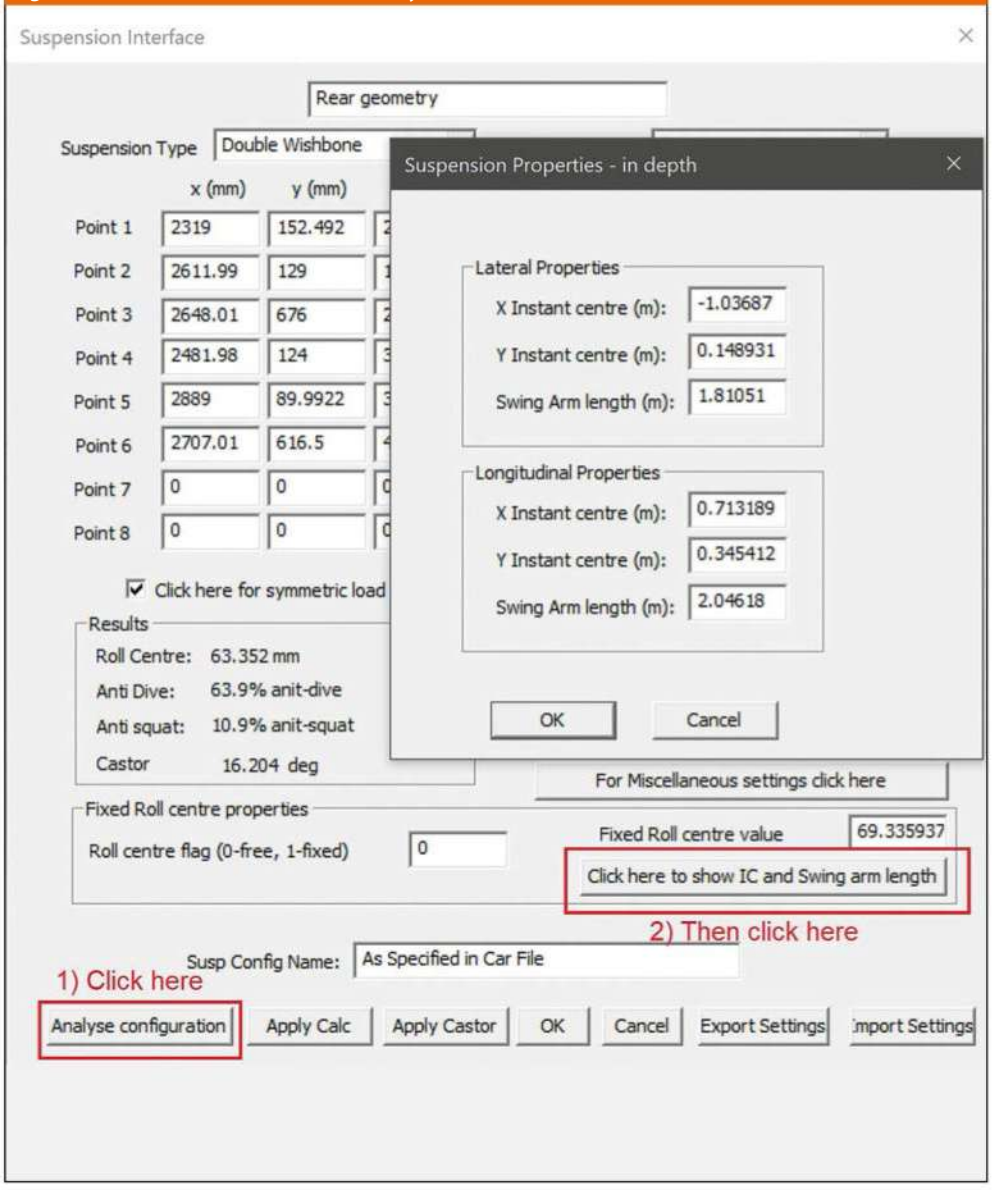


Fig 5: ChassisSim instant centre university



Force-based anti-dive and anti-squat is not just a very powerful way of visualising suspension geometry, it allows you, as an engineer, to quantify what is going on with your geometry correctly. It also starts to answer a lot of those questions that were in your head, but maybe you were too afraid to ask

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Tota Recall

Meet the doctor who has worked in top-level motorsport for more than 30 years and has seen great advancements during that time

By ANDREW COTTON

When he is not fulfilling his role as medical director of Techmed, Vincenzo Tota indulges his passion for racing by competing in marathon rallies with his daughter and his friends. He freely admits his daughter is now more competitive than he is, and that she sometimes admonishes him for being too slow behind the wheel, but it's the challenge he relishes.

In his day job, he leads a group of medical directors and physiotherapists in charge of the medical assistance and physical training of racing teams, on two wheels, four wheels and even sometimes on water.

Currently, the 60-year old attends every race of Porsche's factory sportscar season on both sides of the Atlantic as the team doctor, and has a responsibility to keep all members of the organisation, including its drivers, fit and healthy enough to perform to the required level.

Tota has worked in racing for more than 30 years, having started with BMW before moving to Audi, and then to Porsche, where he and his team are now in charge of the care at the track of more than 50 people at the big events such as the 24 Hours of Le Mans and Daytona. That includes the drivers, the mechanics and engineers working on the cars.

The role goes far further than simply caring for the team. In the event of an accident involving one of his drivers, Tota will attend the medical centre and be on hand to support the doctors where possible, supplying them with medical background for the patient. He will also liaise with engineers at the track, trying to establish the size and direction of forces involved in an accident, to further help the medical staff give the best possible treatment.

Medical background

That's no surprise when you look at his history in medicine. Born in Florence, Italy, he received his degree from the University of Siena

Tota worked in specialised medicine in Italy, the UK, Canada and the US before focusing his attention on the world of motorsport

Tota and one of Audi's air ambulance crew who followed off-road events such as the Dakar Rally. His work to keep all team members fit and healthy is even more critical in such harsh environments

'I would like to see doctors working in motorsport be aware of the situation, be very well informed about doping, and the motorsport regulations'

Whether they're competing on two wheels, four, or on the water, racers need to be kept at the very peak of their physical condition

in 1990 before specialising in Sport Medicine Traumatology at Florence in 1994. He worked as an orthopaedic doctor in Winchester, England and Mount Sinai Hospital in Toronto, while also receiving a Masters in Space Medicine Operations through the flight clinic and mission control for NASA in Houston and Florida.

Racing experience

As a medical student, his love of motorsport began when he competed in off-road events, such as marathon rallies. He crossed the Sahara desert in 1984 and 1985, before being selected for the Italian team to compete in the Camel Trophy, which he won in 1987. He also won the European Offshore Championship in 1999, having won all three races, and contested the World Endurance Offshore Championships in 2000-2002 as the World-European-Italian Champion.

Having studied medicine, rather than follow the career of his father, a chief surgeon in Siena, Tota decided to combine his medical practices with his passion for racing. For that, he needed a route into motorsport, and found it in grand prix racing.

Through friends, he contacted driver, Alessandro Nannini, who was based in Siena, and offered his services to the Italian for free. He offered to provide medical care to the driver, in return for gaining experience in racing.

At the time, Nannini was driving for Benetton in Formula 1 but, just months after their working relationship started, the driver had a helicopter accident that severed his right arm and ended his grand prix career.

A mechanic then introduced Tota to another driver, Luca Maggiorelli, who was driving for the Valier Motorsport BMW team in the DTM in 1991. They reached a similar agreement, whereby Tota's expenses would be covered for the season in return for medical services.

Super Steve

Tota's plan was going well, but it all changed when Steve Soper, who was competing for the Bigazzi team as an official BMW driver, came to Tota with broken ribs after an accident, fearing he wouldn't be able to compete.

'I rang my dad to say this is what's happening, what should I do?' remembers Tota. 'He asked what kind of medicine did I have in the pharmacy. I told him and he said use this one, and do exactly this kind of technique. I'm a very good executor, so you tell me what to do, and I do it exactly as described. I did it, took care of Steve, and the following day he won two races.

'I was very proud of my job, and was expecting him to at least say thank you, but that didn't happen. He went to the podium to celebrate his victory, drank the champagne and then, at the very end of the day, he came to me and asked how much do I owe you for this result? I said, "Nothing, I want to be the doctor for BMW. Could you help?"'

A week later, Tota received a phone call from the Rafanelli BMW team on the recommendation of Soper, who had told them they needed a team doctor, and he was hired. Shortly after that, he was approached by BMW itself, and the following year was looking after the entire BMW squad. That contract lasted for around 20 years and firmly established Tota's name, and his company, in racing.

After that, Tota worked for manufacturers and private teams in all forms of racing. Now he has found a happy home at Porsche.

Practice makes perfect

His job has changed over the years, and today involves more than just attending to the medical needs of a team. To do the job properly, team doctors need to have an understanding of racing, its regulations and the drivers themselves. Tota is therefore advocating that governing bodies introduce a licence to practice at a race circuit, thereby identifying who to turn to in a crisis, as well as training those personnel on how to work with track medics.

His goal, as much as any doctor, is to improve the quality of care for the team at the racetrack, and he has worked tirelessly to push regulators in this direction.

Looking after the health of a team involves far more than just treating aches, pains and accidents

Never one to shy away from a challenge, Tota crossed the Sahara twice in the mid-'80s and was a member of the winning Italian team in the 1987 Camel Trophy. He's also competed in, and won, multiple offshore powerboat championships

Tota has worked with some of the biggest names in motor racing, and observed some even bigger ones, which has helped him understand the evolution of racing drivers

'I was carefully paying attention to the medical kit of the [space] shuttle, and my medical kit is based on that experience, so is very efficient'

'I would like to see doctors working in motorsport be aware of the situation, be very well informed about doping and motorsport regulations,' he says. 'Very often, teams will go for a cheaper option, or the friend of a friend, and maybe they will bring an expert in medicine, but they don't know what's going on.'

Prep work

Tota's work starts away from the track, advising on dietary requirements, collecting the medical history of the drivers, updating himself on the latest regulations and practices that are needed during the event, and then ensuring the right equipment is available to use.

He also puts together training schedules where needed, and runs Porsche's fitness camps and pre-season team building activities. That second bit doesn't always go smoothly; last year the team organised a game of ice hockey in which Tota broke a rib, and then re-broke it tending to a driver in Long Beach, which left him uncomfortable at Le Mans for the 2023 event.

Tota's is a big job, but not one that is always noticed. Doctors are some of the few people in the paddock who should, on a perfect weekend, have nothing to do. That's rarely the case, however. There is *always* something going on at a motorsport event.

Dope demand

Tota operates from his own office at the track, with his own treatment space and medical kit that ensures a team member's ills can be managed, while also remaining on the right side of the doping rules. That latter point is easier said than done. Even the most innocuous drugs may contain a substance that has been banned, and that could lead to a penalty that would have a long-term effect on drivers and their physicians.

'Doping is an issue, where before it was not,' says Tota who, with his team, keeps abreast of the latest doping standards from WADA (World Anti-Doping Agency) and ensures the kit bag they take to each race is up to date in all respects.

'Now you have to be really careful. The doping regulations change every January so you have to read everything to see if there are any changes, and you have to be careful that you don't use something that is a secondary ingredient in a medicine. Even for things like a skin disease, cold or an allergy. You might accidentally take something that is considered doping, and then there is a big damage to the driver's career, and to your career.

'Nowadays, we are really careful in what we take, and we have a special container for medicines that are only available for the mechanics, not the drivers.'

That is not to say the whole team is considered the 'normal population', as Tota describes it. It's also the driver assistant and driver physiotherapists who must be clean of all drugs that could be considered a doping agent. That issue recently became global news in tennis, for example.

Space kit

Understandably, great care is taken with items such as the medical kits, which accompany each of his doctors to an event. Each kit has precisely the same layout, so any one of his doctors already knows which drawer holds the aspirin, and which the bandages. Each is assembled to a design Tota developed from his time with the NASA programme.

'I was carefully paying attention to the medical kit of the shuttle,' he acknowledges, 'and my medical kit is based on that experience, so is very efficient.'

The amount of equipment that will be taken to each event depends on the length of the race. For a shorter race Tota will carry 21kg of equipment, but for Le Mans that goes up to 65kg, partly due to the increased size of the team at the track.

After 20 years working with BMW, Tota moved to Audi for a stint before switching to Porsche. Today, he looks after a team of more than 50 at any of the big events the manufacturer competes in

The role of doctors, and the wider world of medicine, in motor racing has changed beyond all measure during Tota's career, and he continues to spearhead the drive for effective medical care for all

This attention to detail has been honed after also studying some of the great drivers. Tota has worked with some of the biggest name drivers in the sport, including Nelson Piquet, Alex Zanardi, Tom Kristensen and Mark Webber. However, he was also able to watch the likes of Ayrton Senna and Michael Schumacher from close range.

He didn't work with those two drivers directly, but studied their approach to understand how the next generation of driver would evolve. Senna's approach to both mental health and strength, followed by fitness, was taken to the next level by Schumacher. The two examples helped shape Tota's view of how a team doctor might work with a driver in the future.

'It was the first time that it became a different discipline,' he says. 'I studied Senna a lot and how he did it, and that was the beginning of my experience in how to keep drivers at a good fitness level for racing.'

Designer suit

Still, there is a limit between what a driver can do to remain fit, and what the designers and engineers are doing to create speed. The human may not be foremost in the minds of some designers as they pen the fastest car possible, but Tota's primary focus is that driver, and he does all he can to try to get the designers to think about the human controlling their car.

He didn't work with [Ayrton Senna and Michael Schumacher] directly, but studied their approach to understand how the next generation of driver would evolve

That led him into the world of road car design through BMW's link with McLaren, having provided the engine to the now-legendary F1 in the early 1990s. Working with designer, Gordon Murray, and McLaren's Jeff Hazell, Tota helped improve the in-cabin ergonomics for the driver before the car went into production. He took the lessons learned there back into racing.

He was also involved in McLaren's racing programme, notably as a doctor when JJ Lehto returned to driving after breaking his neck in 1994. The Finn recovered to drive the McLaren F1 GTR to Le Mans victory in 1995.

He also worked with Nelson Piquet when the Brazilian broke his legs in a practice crash for the Indianapolis 500 in 1992. Although Dr Terry Trammell performed the operation on Piquet's legs, it was at Tota's clinic in Siena that Piquet went through his rehabilitation.

Tota was also close friends with Alex Zanardi, who lost his legs in a crash in 2001, but later returned to racing in the World Touring Car Championship for BMW, and then turned to the Paralympics, winning four gold medals.

Medical advice

The medical world has changed significantly since the start of Tota's time in racing.

Gone are the days when a doctor might split the medical kit into smaller parts, hand them to the mechanics, and then re-assemble the kit at the track to get around different countries' customs regulations.

Tota and his team hold licences to practice medicine in many countries, and have worldwide insurance, but there are still rules that are meticulously followed. He has also developed close working relationships with the FIA, and the medical delegates around the world, to further improve the quality of care for his team.

The attitudes of drivers have also changed. Where now they might leave to stay in a hotel if one of their children is ill ahead of a big race, in the past that wasn't necessarily the case.

'I was dealing with a very famous champion, a Brazilian driver, and before the race he was eating bean soup. I said to him that this was not really the best food, but he replied that he had won three world championships on bean soup, so he was going to keep doing it.'

The motor racing world did, indeed, change in the 1990s, and not only through the likes of Senna and Schumacher. The medical services available at the circuits improved, and are now of paramount importance, and Tota will keep pushing to make the entire motorsport medical system more effective.

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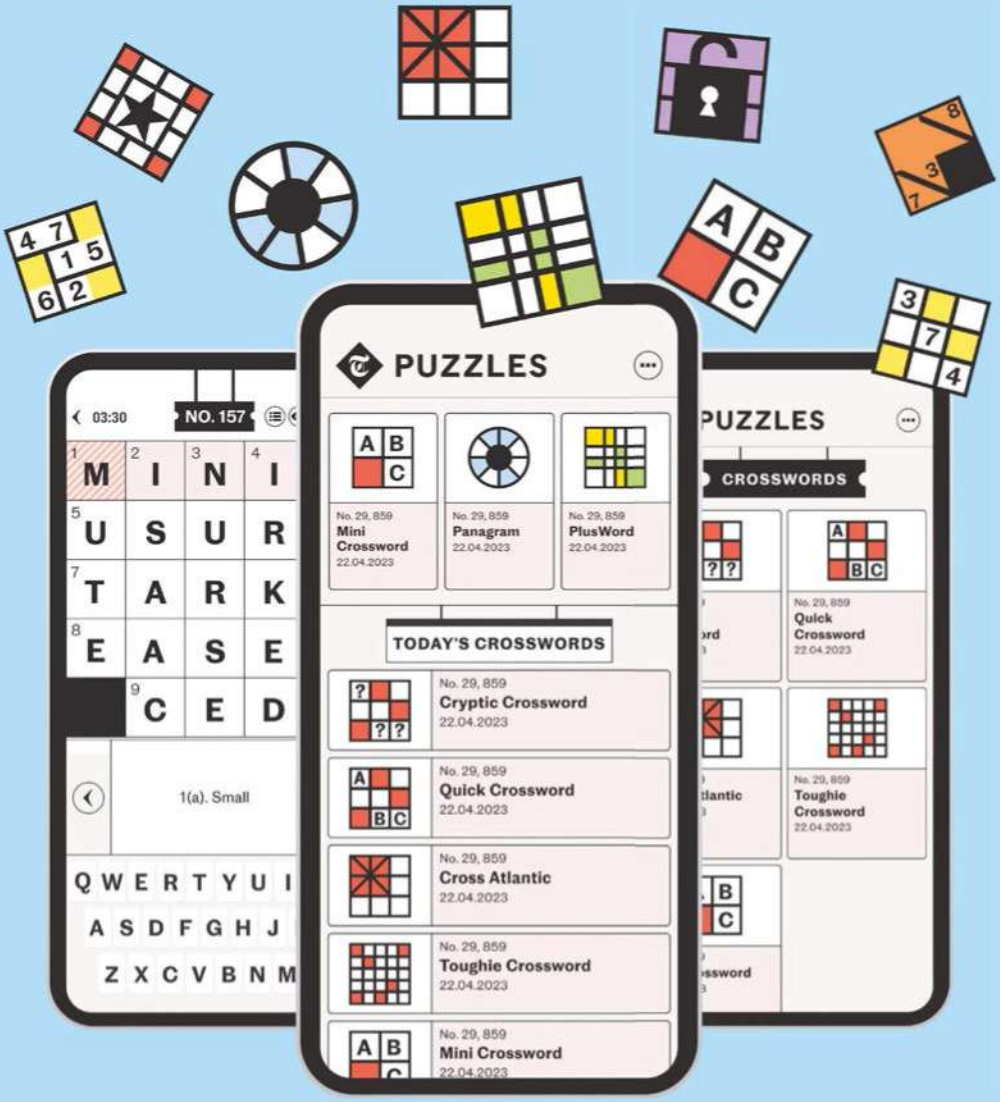

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IN BRIEF

McLaren has unveiled the Artura Trophy EVO, which is eligible for the **McLaren Trophy** from 2025 onwards. Features added include a push to pass button, wider tyres and improved brake and engine cooling. New uprights feature two-way adjustable dampers and stiffer anti-roll bars that offer greater adjustability options. The car will be built from production line models and customers of the existing car can upgrade.

This year's **FIA Motorsport Games**, held in Valencia, Spain, will include Cross Car Mini offroading as one of the categories. The Games will feature a record 28 disciplines as part of a massive sporting expansion for the third edition. Cross Car Senior and Cross Car Junior were part of the bill in 2022, but this opens the door for competitors aged between eight and 12 to race for their nation.

The **Macau Grand Prix** will host Formula Regional cars for the first time, and has attracted teams from Japan, America, Oceania and the Middle East to the event taking place in November. A dozen teams have signed up to take part, alongside the GT World Cup.

Lewis Hamilton's decorated race engineer, **Peter Bonnington**, will not follow the seven-time Formula 1 world champion to Ferrari next year after 12 seasons together. Bonnington is instead remaining with Mercedes, which has promoted him to head of race engineering.

Bill York, who worked in and managed the Indianapolis Motor Speedway media centre for more than 50 years, has died at the age of 91. He had various media roles between the late 1950s and the mid-2010s.

PalmerSport will once again partner with **Ginetta** to offer its customers a scholarship programme that will allow them to compete for a fully financed, full-time drive in the following season's Ginetta GT Academy series. The PalmerSport x Ginetta Scholarship includes two assessment days at Bedford Autodrome ahead of a two-driver shootout at Donington Park.

Supra GT4 gets update

After customer feedback, Toyota has rolled out its second EVO update in as many years. The EVO2 is priced at €202,000 - €16,000 more than its predecessor

Toyota has launched another updated version of its Supra GT4 and started to take orders for the car, which is set to debut in the IMSA Challenge round at Daytona in January. The Toyota GR Supra GT4 EVO2 features re-tuning of the ABS maps and a software update for more precise rev-matching under downshift. Changes have also been made to the engine cooling, brakes, drivetrain and cockpit temperatures.

Toyota Gazoo Racing, which has developed the car, has tested it extensively to collate feedback from teams and drivers. Sales of the original Supra GT4 have surpassed 120 units since its launch in 2020.

New BTCC feeder car unveiled

The British Touring Car Championship has unveiled the design of its new feeder support series car that will debut next year. The Chevron B1417 will be used in the TOCA Junior Championship for drivers aged 14-17. Designed for an easy and safe transition from karting to cars, the vehicle features an FIA-homologated rollover protection system with 16mm main hoop, side impact panelling and energy-absorbing materials. It weighs 850kg and is powered by a bespoke four-cylinder, naturally-aspirated 1.8-litre engine. The five-speed manual gearbox and limited slip differential will be sealed to curb development. Suspension consists of front and rear anti-roll bars and sealed two-way dampers with controlled springing. Aerodynamic features include a splitter and adjustable rear wing. The front and rear subframes can be detached separately for ease of access. BTCC supplier, Goodyear, will provide its Direzza racing tyre for the 10-round TOCA Junior season.

JEP/Dom Gibbons

Graves Motorsport became the first team to commit to the new, rear-wheel-drive, TOCA Junior car

Revolution's US backing

Revolution Race Cars, the UK-based sportscar manufacturer, has secured backing and presence in the United States from two of its customers, that will allow it to fast-track the development of new models to its line up of customer-focused prototype racecars.

The company says that it remains committed to making Le Mans Prototype technology and safety more accessible, offering vehicles equipped with carbon tubs and cutting-edge features.

The backing comes from a new American company, Cabotage Corporation, which is an investment vehicle formed by Classic Car Club Inc. directors Zan Moseley, Revolution Race Cars leadership Phil Abbott and Nigel Redwood, together with Revolution customers Marc Russell and Channel Islands-based entrepreneur Terry Thompson, have acquired 100 per cent of the issued share capital of Abbott Automotive Limited, trading as Revolution Race Cars. Revolution's latest product, the 500 EVO, was launched earlier this year.

Isotta Fraschini withdraws

The number of privateers to withdraw from the FIA World Endurance Championship grew longer at the end of August as Isotta Fraschini confirmed the end of its Hypercar endurance racing programme with immediate effect.

The Italian manufacturer parted company with its motorsport boss, Claudio Berro, in July and then confirmed the cessation of activity shortly before the sixth round of the WEC season at Austin. 'There are no longer any conditions to continue the partnership,' read a statement from Isotta regarding its operational partner, Duqueine Team. The brand added that it 'has decided to redirect its resources toward restructuring its motorsports programme and expanding its track and road car activities.'

Isotta hired Michelotto to develop the hybrid-powered Tipo 6 Competizione, which finished 14th at Le Mans this year

Isotta joins the likes of former LMP1 competitors, BR Engineering and DragonSpeed, and more recently the Glickenhaus Hypercar outfit, in exiting the WEC's top class that now boasts eight major OEMs. One reason for this latest withdrawal is thought to be the rule that manufacturers must run two cars next year, adding to their costs and squeezing further the existing grid places.

NEW ENTRY-LEVEL BMW RACER

BMW is working on a new entry-level racecar that will sit below GT4, and will succeed the BMW M2 CS Racing upon its introduction in 2026. 'Proximity to our customers is one of the maxims we pursue at BMW M Motorsport,' says Bjorn Lellmann, head of customer racing at BMW M Motorsport. 'From our point of view, this also includes offering a car for grassroots racing that teams and newcomers to racing can afford.'

Wheatley joins Audi

Red Bull Racing sporting director, Jonathan Wheatley, has joined Audi's new Formula 1 project after 18 years and six Constructors' Championship titles with the Milton Keynes-based team. Wheatley will leave Red Bull to become Audi's team principal, spearheading the project alongside new chief technical and operational officer, Mattia Binotto.

It will be Wheatley's first team manager role. The Brit, who started his F1 career with Benetton in the 1990s and rose to the title of chief mechanic, is due to start his new position by July 2025. He will remain with Red Bull until the end of the current season before going on gardening leave.

'Jonathan has played a major part in many race victories and World Championship titles in his Formula One career so far and has extensive experience in the paddock,' commented Audi CEO and Sauber chairman, Gernot Döllner. 'He is a very valuable addition to our team. With the appointment of Jonathan and Mattia, we have taken a decisive step towards our entry into Formula 1. I am convinced that, with the two of them, we have been able to combine an extremely high level of competence for Audi.'

Red Bull, which announced the news three hours before Audi, stated that the change 'provides opportunity to elevate others' within the team to senior positions. At the time of writing, a new sporting director had not been announced.

Lambo's next GT3 platform emerges

Temerario will be the base for Lamborghini's next GT3 and Super Trofeo cars, with the latter due to arrive in 2027. The road version is a hybrid, but the electric aspect will be removed per GT3 rules

Lamborghini has launched the Temerario, successor to the Huracán road car, that will form the basis of the company's new GT3 challenger arriving in 2026.

The new car features a new V8 twin-turbo that is made at Lamborghini's headquarters in Sant'Agata Bolognese.

The engine is understood to have not come from Audi, nor is it based on the V8 twin-turbo that powers the SC63 LMDh.

Originally Lamborghini's LMDh car was to use this engine, but the team found it was too compromised for racing, and chose instead to develop an engine from external supplier, Autotecnica Motori.

The Temerario chassis will also be made in Sant'Agata, unlike the Huracán which was based on the Audi R8 platform. This, then, will be the first in-house GT3 from Lamborghini. Testing of the new racecar is scheduled to begin early next year.

Audi currently has no successor to the R8 GT3, but could take the Temerario chassis as the basis of its next supercar if the green light is given by the executive board.

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Inside the world of modern motorsport technology

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Flexible friends

Since the advent of wings, flexible bodywork has been a hot topic

From the moment the basic concept of how wings on a racing car worked was understood, there started a battle to generate downforce while reducing drag. It wasn't a complicated thought process. Downforce equalled speed in the corner; drag reduced it on the straight. That was apparent from the moment Chris Amon, driving a Ferrari 312 fitted with a rudimentary strut-mounted rear wing, took pole position for the 1968 Belgian Grand Prix nearly four seconds quicker than the second-placed Matra of Jackie Stewart, and nearly six seconds clear of his wingless Ferrari teammate, Jacky Ickx. Others copied the concept from the next race onwards, and from then on it was a fast, almost brakeless train as aerodynamics became better understood. Wings became more effective, producing more downforce. They started to change roles, directing air into areas of the car where it would be most needed. As a result, car performance increased.

There were a few side-tracked issues, such as the sliding skirts developed for the Lotus 79, but these were more for reducing the amount of air entering the underfloor tunnels from the side than about reducing drag. That meant only the air that was being channelled under the car was in those tunnels, and the result was devastating for the competition in 1978. As other cars adopted tunnelled underfloors (more easily with a V8 engine than a flat-12 which took up lots of potential tunnel area) so skirts advanced until they were banned.

A request to see the camera data has, unsurprisingly if disappointingly, been rejected

Regulatory battles

Since then, flexible bodywork has been the bane of regulators. The thickness of bodywork and shut lines can make a big difference. Ask anyone involved in one-make racing - they all buy as many front wings, noses, engine covers and rear wings as they can, run all combinations and work out which produces the least amount of drag.

From Red Bull's front wing sagas to Porsche neglecting to connect the rear deck of its LMP1 car to the rear wing mainstay (the team said this was pre-production and it always intended to connect it) and Toyota turning up at Le Mans with a flexible rear wing main plane, the amount by which bodywork may flex has been re-defined ad nauseum. The problem, then, is regulating by how much the bodywork, or wing, may flex within the set legal limit. Of course, scrutineering only demonstrates that a car is safe when it is static. Load tests have been introduced to ensure that on a prescribed axis, the bodywork flex remains within regulation. The task of the engineer is to make sure it bends in other ways while obeying the rule book.

In September 2023, the FIA issued a Formula 1 Technical Directive aimed at the mounting of the nose to the chassis. 'We believed there was a need for clarity,' said FIA single seater technical director at the time, Tim Goss. Since then, there has been more clarification.

Mid-season checks

At this year's Belgian GP, the FIA asked several teams to run sideways-facing cameras to monitor front wing rotational flex. These nose-mounted devices took images in 4K that were given to the FIA post-session. Measures were taken to ensure teams didn't fit compliant noses for the sake of the testing and then revert to non-compliant ones for the race.

A request to see the camera data has, unsurprisingly if disappointingly, been rejected. There's clearly something in that data that would be a competitive advantage if rivals got their hands on it, but that's half the fun. It's interesting that the FIA continues to clarify rules, rather than point the finger at any one team.

This is the latest in a series of updates to the Formula 1 technical regulations as the FIA seeks to close the loopholes that exist, or could potentially exist. It seems there has also been a clarification on the amount of pressure that can be exerted onto one or other brake disc. Before, the regulations only implied that the brake pressure had to be the same on both wheels of the same axle, whereas now it is stated. This led to rumours that teams had been experimenting with brake steer, helping the car to rotate around a corner, although media reports have said this is not the case. Apparently, the mere implication that the two discs needed to have the same pressure applied created a grey area.

Given there are so many technical working groups and that they all are working towards a common goal, in this case the 2026 regulations, the matter must have arisen. Which means that someone was thinking about it and elected to raise it as a concern rather than invest in it. That, or the FIA has gone through a process of evaluating and perfecting its rule set, taking preventative measures rather than waiting for teams to waste their precious time and money on something that would be banned anyway. I just hope that there is still room for a little fun.

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